

**BLACKSTONE RIVER BASIN
MILLBURY, MASSACHUSETTS**

**RAMSHORN POND DAM
MA 00145**

PHASE I INSPECTION REPORT NATIONAL DAM INSPECTION PROGRAM

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**DEPARTMENT OF THE ARMY
NEW ENGLAND DIVISION, CORPS OF ENGINEERS
WALTHAM, MASS. 02154**

JULY 1978

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NATIONAL PROGRAM OF INSPECTION OF NON-FEDERAL DAMS
DRAFT REPORT REVIEW COMMENTS

DOROTHY POND

DAM, IDENTITY NO. MA 00146

RAMSHORN POND

MA 00145

FOUNDATIONS & MATERIALS BR.

General Comment: These two (2) reports are good and are similar to ROBINSON POND DAM, MA 00670, in format and content. All review comments (ATTACHED) made for ROBINSON POND DAM shall be considered applicable to these two reports (MA 00145 & 00146)

C. L. Pierod

FOUNDATIONS & MATERIALS
BRANCH

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SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

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19. KEY WORDS (Continue on reverse side if necessary and identify by block number) DAMS, INSPECTION, DAM SAFETY, Blackstone River Basin Millbury, Mass.		
20. ABSTRACT (Continue on reverse side if necessary and identify by block number) Ramshorn Pond Dam has a maximum height of 25 feet and is approximately 560 feet long. Generally the dam is considered to be in fair condition. The test flood is equal to $\frac{1}{2}$ the PMF. An outflow of 2,670 cfs would overtop the dam by 1.4 feet.		

RAMSHORN POND DAM

MA 00145

BLACKSTONE RIVER BASIN
MILLBURY, MASSACHUSETTS

PHASE I INSPECTION REPORT
NATIONAL DAM INSPECTION PROGRAM

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PHASE I INSPECTION REPORT

BRIEF ASSESSMENT

Identification No.: MA00145

Name of Dam: Ramshorn Pond

Town: Millbury

County and State: Worcester County, Massachusetts

Stream: Tributary of Blackstone River

Date of Inspection: June 12, 1978

Ramshorn Pond Dam which was originally constructed around 1825 is an earthfill dam. The dam has a maximum height of 25 feet and is approximately 560 feet long. The outlet conduit is a 24-inch diameter pipe controlled by a rack and pinion operated gate valve. The spillway consists of a mortared stone paved channel that discharges into an earth channel. Wooden flashboards 19 inches high are located on the spillway crest.

There are no plans, specifications, or computations available from the Owner, County, State, or Town offices regarding the design, construction, or repairs of this dam except for three drawings included in Appendix B showing proposed modifications.

Due to its age, Ramshorn Pond dam was neither designed nor constructed by current approved state-of-the-art methods. Based upon the visual inspection at the site and a review of the limited engineering data available, there are areas of concern which must be corrected to assure the continued performance of this dam. Generally, the dam is considered to be in fair condition. However, there are several visible signs of distress which indicate a potential hazard at this site: slight seepage at the downstream toe of the dam, a pool of water on the downstream toe, erosion on the upstream face and downstream face of the dam, small

trees and brush on the dam, minor accumulation of debris in the spillway channel, slumped riprap on the upstream face, leakage of the gate valve stem, a large animal burrow and numerous chipmunk holes on the dam face.


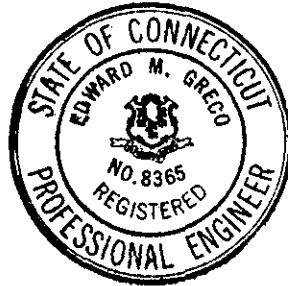
There are several factories and numerous residences located about 3,000 to 4,000 feet downstream from the dam. In the event of dam failure, many lives could be lost and appreciable property damage would occur.

Hydraulic analyses indicate that the existing spillway without flashboards can discharge a flow of 770 cubic feet per second (cfs) at Elevation (El) 631.7 which is the average top of the dam. An inflow test flood of 2,040 cfs (one-half of the probable maximum flood) would overtop the lowest point on the main dam by about 0.2 feet. The spillway capacity is inadequate for the 100 year storm unless the flashboards are permanently removed and the walkway above the flashboards is eliminated. Freeboard is inadequate and raising the dam should be considered.

In the event of dam failure, a possible hazard does exist for the downstream inhabitants. Because of this hazard potential and the lack of available design and construction data, it is recommended that the Owner employ a qualified consultant to investigate the seepage and pool of water at the downstream toe and to conduct a more detailed hydraulic and hydrologic study. In addition, erosion of the upstream and downstream face should be repaired and riprap replaced and/or repaired to prevent continued deterioration of the dam. Also, it is recommended that the Owner remove the brush and trees on the dam, clear all debris from the spillway, and fill in all animal burrows.

The above recommendations should be implemented within a period of 1 to 2 years after receipt of the Phase I Inspection Report. An alternative to these

recommendations would be draining the reservoir and breaching or removing the dam.



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This Phase I Inspection Report on Ramshorn Pond Dam has been reviewed by the undersigned Review Board members. In our opinion, the reported findings, conclusions, and recommendations are consistent with the Recommended Guidelines for Safety Inspection of Dams, and with good engineering judgment and practice, and are hereby submitted for approval.

CHARLES G. TIERSCH, Chairman
Chief, Foundation and Materials Branch
Engineering Division

FRED J. RAVENS, Jr., Member
Chief, Design Branch
Engineering Division

SAUL C. COOPER, Member
Chief, Water Control Branch
Engineering Division

APPROVAL RECOMMENDED:

JOE B. FRYAR
Chief, Engineering Division

PREFACE

This report is prepared under guidance contained in Recommended Guidelines for Safety Inspection of Dams, for a Phase I Investigation. Copies of these guidelines may be obtained from the Office of Chief of Engineers, Washington, D.C. 20314. The purpose of a Phase I Investigation is to identify expeditiously those dams which may pose hazards to human life or property. The assessment of the general condition of the dam is based upon available data and visual inspections. Detailed investigation, and analyses involving topographic mapping, subsurface investigations, testing, and detailed computational evaluations are beyond the scope of a Phase I investigation; however, the investigation is intended to identify any need for such studies.

In reviewing this report, it should be realized that the reported condition of the dam is based on observations of field conditions at the time of inspection along with data available to the inspection team. In cases where the reservoir was lowered or drained prior to inspection, such action, while improving the stability and safety of the dam, removes the normal load on the structure and may obscure certain conditions which might otherwise be detectable if inspected under the normal operating environment of the structure.

It is important to note that the condition of a dam depends on numerous and constantly changing internal and external conditions, and is evolutionary in nature. It would be incorrect to assume that the present condition of the dam will continue to represent the condition of the dam at some point in the future. Only through continued care and inspection can there be any chance that unsafe conditions be detected.

Phase I inspections are not intended to provide detailed hydrologic and hydraulic analyses. In accordance with the established Guidelines, the Spillway Test flood is based on the estimated "Probable Maximum Flood" for the region (greatest reasonably possible storm runoff), or fractions thereof. Because of the magnitude and rarity of such a storm event, a finding that a spillway will not pass the test flood should not be interpreted as necessarily posing a highly inadequate condition. The test flood provides a measure of relative spillway capacity and serves as an aid in determining the need for more detailed hydrologic and hydraulic studies, considering the size of the dam, its general condition and the downstream damage potential.

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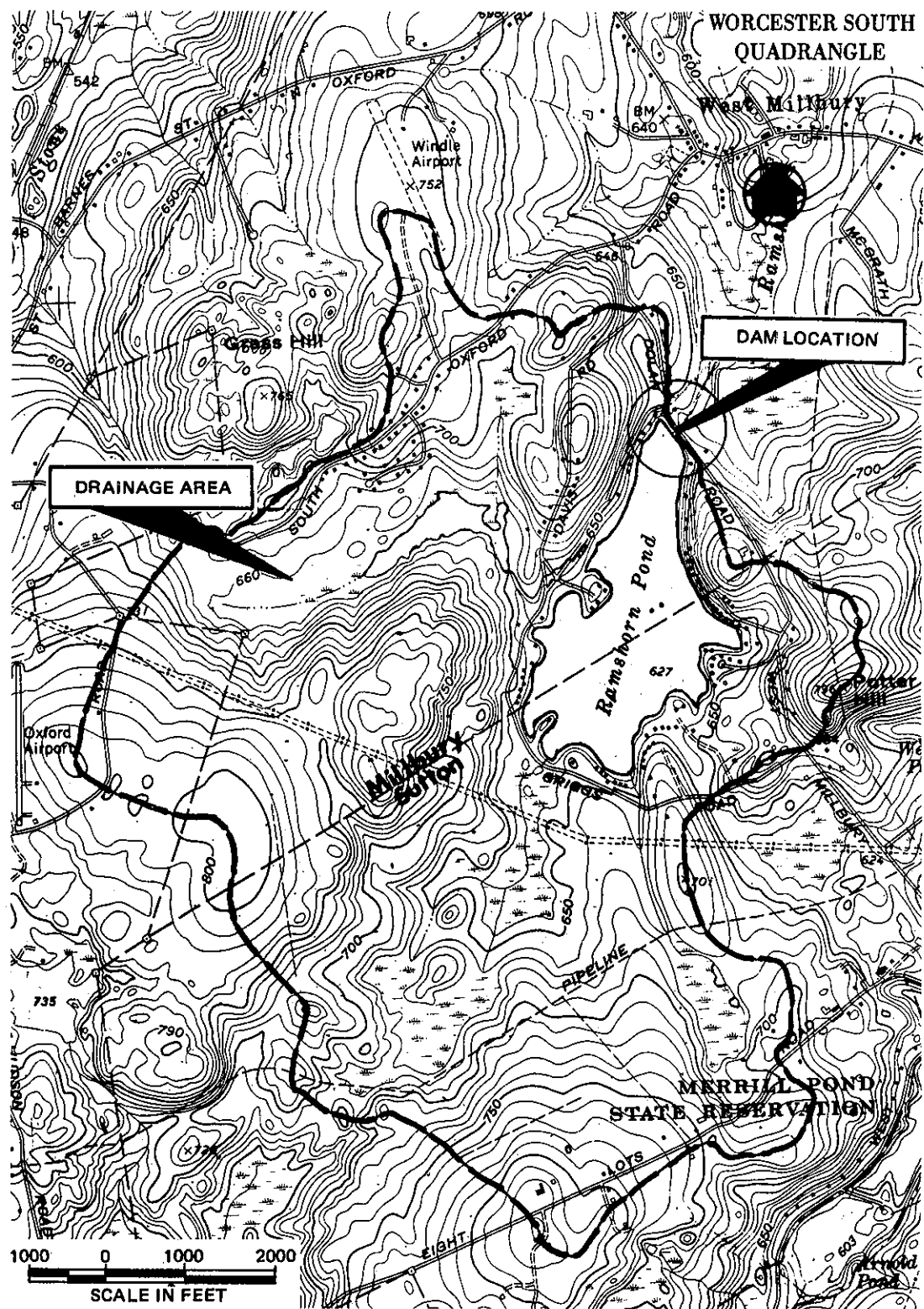
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**OVERVIEW
RAMSHORN POND DAM
MILLBURY, MASSACHUSETTS**



DAM CREST (DOLAN ROAD) AND RAMSHORN POND

LOCATION AND DIRECTION OF
PHOTOGRAPHS SHOWN ON FIGURES
IN APPENDIX B



LOCATION MAP - RAMSHORN POND DAM

NATIONAL DAM INSPECTION PROGRAM

PHASE I INSPECTION REPORT

RAMSHORN POND

SECTION 1

PROJECT INFORMATION

1.1 General

a. Authority. Public Law 92-367, August 8, 1972, authorized the Secretary of the Army, through the Corps of Engineers, to initiate a national program of dam inspection throughout the United States. The New England Division of the Corps of Engineers has been assigned the responsibility of supervising the inspection of dams within the New England Region. Metcalf & Eddy, Inc. has been retained by the New England Division to inspect and report on selected dams in the State of Massachusetts. Authorization and notice to proceed was issued to Metcalf & Eddy, Inc. under a letter of May 3, 1978, from Ralph T. Garver, Colonel, Corps of Engineers. Contract No. DACW 33-78-C-0306 has been assigned by the Corps of Engineers for this work.

b. Purposes

- (1) Perform technical inspection and evaluation of non-Federal dams to identify conditions which threaten the public safety and thus permit correction in a timely manner by non-Federal interests.
- (2) Encourage and assist the States to initiate quickly effective dam safety programs for non-Federal dams.
- (3) To update, verify and complete the National Inventory of Dams.

1.2 Description of Project

a. Location. The dam is located in the Town of Millbury, Worcester County, Massachusetts, on

Ramshorn Brook, a tributary of the Blackstone River. Approximately 50 percent of Ramshorn Pond and its drainage area is in the Town of Sutton.

b. Description of Dam and Appurtenances.

Ramshorn Pond Dam is an earthfill dam approximately 560 feet long and 25 feet high (see Appendix B, Figures B-1, B-2 and B-3). The dam crest is Dolan Road which is paved and relatively straight. The dam has a maximum crest width of 21 feet and has upstream and downstream slopes of 2:1 (horizontal to vertical). The upstream slope is riprapped while the downstream slope is earth and covered with grass, trees and brush. At the end of the outlet conduit the slope is maintained by an 8-foot high vertical mortared stone headwall.

The spillway, situated near the northern end of the dam, is 18 feet wide and 5.2 feet deep under Dolan Road, with a concrete and stone headwall on the upstream face. The spillway crest elevation is 625.5. The upper 120 feet of the spillway channel is paved with stone and is comprised of a sloping section and a stepped section, and 2-foot high mortared stone retaining walls. Below the paved section, the spillway discharges into an earth channel. Wooden flashboards 19 inches high are located on the spillway crest.

Outlet control for the dam is a 24-inch diameter pipe which extends from the upstream face of the dam to a mortared stone headwall on the downstream face about 140 feet south of the spillway centerline. Invert elevation at the outlet is 609.4. The gatehouse, which is recessed in the downstream slope of the dam, consists of a small wooden shed covering a circular dry stone well 7.5 feet in diameter and 6.5 feet deep. Inside the locked gatehouse is a platform of wooden planks built around the handwheel-type rack and pinion gear, which operates a gate valve on the outlet conduit.

- c. Size Classification. The maximum height of the dam is about 25 feet. The maximum storage of Ramshorn Pond is 2,200 acre-feet, which places this dam in the "intermediate" category.
- d. Hazard Classification. The community of West Millbury is located less than 1 mile downstream from the dam. Most of the lower Ramshorn Brook area between Dolan and West Main Street is meadow and swamp land. However, in the event of dam failure, the flood wave could cause extensive damage downstream and, possibly, could cause considerable loss of life. Therefore, the dam has been placed in the "high" hazard category.
- e. Ownership. The dam is presently owned by the Massachusetts Electric Company, 939 Southbridge Street, Worcester, Massachusetts, 01610. Mr. Barry Huston, District Superintendent (617-791-8511) granted permission to enter the property and to inspect the dam and the gatehouse.
- f. Operator. The Massachusetts Electric Company has the key for the lock on the gatehouse and has personnel who are the only operators for the dam.
- g. Purpose of the Dam. The dam was originally constructed as a storage dam for the Blackstone Canal Corporation. Subsequently, it was controlled by the Ramshorn Pond Co., an association of 21 mills downstream of the dam that used the water. Eventually, American Steel & Wire Co. and the Worcester Electric Light Co. shared responsibility for the dam. By 1960, Worcester Electric Light had joined Massachusetts Electric and was using the pond as storage for cooling water at the Webster Street Power Generating Station in Worcester. That station has since been closed down, and although Massachusetts Electric maintains the dam, they no longer use the water stored behind it. Presently, the pond is used for recreation by local residents.

- h. Design and Construction History. There are no plans, specifications, or computations available from the Owner, County or State offices relative to the design or construction of the dam as built in 1825. Records at the Worcester County Engineer's office indicate that the dam was rebuilt and raised in 1872. The core wall was constructed of chestnut planking and had puddled fill. An 1896 plan of the dam filed with the County Commissioners on behalf of the Ramshorn Pond Co. shows a straight, short (90 feet), narrow spillway and a 30-inch outlet pipe through the dam (see Figure B-1, Appendix B).

Records at the Worcester County Engineer's office state that in about 1915, the spillway was rebuilt with a substantial cutoff wall placed near the centerline of the dam. Until 1939, only minor changes and repairs were made to the roadway and dam, including repairs made to the spillway apron at the embankment toe, additional riprap to the upstream face, and brush and tree removal from the spillway channel and the downstream slope. The 1939 plans (Figures B-2 and B-3 in Appendix B) show the present dam configuration although the number and arrangement of flashboards has been modified.

1. Normal Operational Procedure. Since the Webster Street power station is closed, Massachusetts Electric has no further use for the water in Ramshorn Pond. Currently, the procedure is to maintain the recreational level of the pond as a service to local residents. This is done by seasonally opening and closing the gate valve on the 24-inch outlet pipe which passes under the dam embankment.

The spillway at Ramshorn Pond is ungated. The only restriction to flow besides the flashboards is the walkway above the flashboards and the bridge over the spillway. The flashboards existing at this time are 1.6 feet above the spillway crest. Previous inspection reports on file at the Worcester County Engineer's office show that the height of the flashboards in the past has ranged from 1 to 3 feet, and for some periods the

flashboards were missing altogether. It was indicated that the flashboards may be removed in the event of hurricane warnings.

1.3 Pertinent Data

- a. Drainage Area. The drainage area above Rams-horn Pond Dam is approximately 1,550 acres (2.4 square miles) of gently rolling wood and swampland. Development is limited to housing on the perimeter of the pond and along Millbury and Eight Lots Roads, the only two major roadways passing through the drainage area.
- b. Discharge at Dam Site. Uncontrolled discharge above El 627 flows over the flashboards and down the 18-foot wide concrete spillway. The spillway, which has a crest elevation of 625.5 feet, is 5.2 feet high at the upstream end (under Dolan Road). The spillway channel slopes for about 90 feet, decreases in elevation in steps to El 611 where the paved channel and stone masonry sidewalls end. From there, the flow discharges into an earth cut channel that flows roughly parallel to the dam crest and joins Ramshorn Brook below the outlet.

The spillway without the flashboards can discharge an estimated 770 cfs at El 631.7 which is the average top of the dam. An in-flow test flood of 2,040 cfs (half of the probable maximum flood) will overtop the lowest point on the main dam by 0.2 feet.

The maximum flood at the dam site is unknown, however, past inspection records state that the dam was overtopped in the 1938 flood and that the dam crest had to be sandbagged. This overtopping could have been the result of wave action. Further, the records show that in the 1955 floods the water flowed about 4 feet above the spillway crest and did not overtop the dam.

- c. Elevation (feet above MSL (Mean Sea Level)).
A benchmark elevation of 627 at the top of the flashboards was estimated from a United States Geological Survey (USGS) topographic map.
- (1) Top dam: 631.5 to 633.5
 - (2) Maximum pool-design surcharge: 631.5
 - (3) Full flood control pool: N/A
 - (4) Recreation pool: 627 (top of flashboards)
 - (5) Spillway crest (ungated): 625.5
 - (6) Upstream portal invert diversion tunnel: N/A
 - (7) Stream bed at centerline of dam: 607.9
(Invert of outlet conduit)
 - (8) Tailwater: 609.9 (Outlet conduit closed)
- d. Reservoir
- (1) Length of maximum pool: 4,400 feet
 - (2) Length of recreation pool: 4,400 feet
 - (3) Length of flood control pool: N/A
- e. Storage (acre-feet)
- (1) Recreation pool: 2,200 (Approximate)
 - (2) Flood control pool: N/A
 - (3) Design surcharge: 770 at El 631.7
(Above spillway crest El 625.5)
 - (4) Top of dam: 3,000
- f. Reservoir Surface (acres)
- (1) Top dam: 125

- (2) Maximum pool: 125
- (3) Flood-control pool: N/A
- (4) Recreation pool: 125
- (5) Spillway crest: 125

g. Dam

- (1) Type - Main dam: earthfill
- (2) Length - Main dam: 560 feet
- (3) Height - Main dam: (maximum) 25 feet
- (4) Top width: 21 feet (Dolan Road)
- (5) Side slopes - Main dam: Upstream 2:1;
downstream 2:1
- (6) Zoning: Unknown
- (7) Impervious core: Chestnut Planking
along centerline 20 feet - puddled fill
- (1873)
- (8) Cutoff: Unknown
- (9) Grout curtain: Unknown

1. Spillway

- (1) Type: Broad crest
- (2) Crest length: 18 feet
- (3) Crest elevation: 625.5
Top of flashboards: 627.0
- (4) Gates: None
- (5) Upstream Channel: Concrete headwalls
- (6) Downstream Channel: 18-foot wide
mortared stone with 2-foot high training
walls steps down to earth channel
- (7) General: Spillway channel makes sharp
90 degree bend about 100 feet from dam.

- j. Regulating Outlets. The only apparent regulating outlet is a 24-inch diameter outlet conduit which extends from a point 40 feet into Ramshorn Pond, passes under the dam embankment and outlets at a masonry headwall. The invert of the conduit outlet is at El 610.2. The gate for the conduit is opened by means of a rack and pinion mechanism inside the gatehouse; water flows through the conduit into a small stilling pool that was about 1.7 feet deep at the foot of the headwall during the inspection. From the pool, water flows approximately 50 feet downstream where it joins flow from the spillway channel. Further downstream, the brook flows through a low wooded area and swampland.

SECTION 2
ENGINEERING DATA

- 2.1 General. There are no plans, specifications, or computations available from the Owner, State, or County offices relative to the original dam built in 1825. A tracing of an 1892 Dam Plan was obtained from the Worcester County Engineer's office showing a spillway and a 30-inch outlet pipe (Appendix B, Figure B-1). Subsequently, major changes were made to the dam in 1939 without the approval of the County Commissioners. Two drawings of the rebuilt dam showing a Dam Plan and Profile along Dolan Road, and a Plan of the Spillway and Dam Section were obtained from the Worcester County Engineer's office. The 1939 plans show the dam much as it is today (Appendix B, Figures B-2 and B-3).

Other data used for this evaluation included review of previous inspection reports and conversations with the Owner and personnel from Town, State and County agencies.

The information available is such that the assessment of the condition of the dam must be based primarily on the visual inspection and the past operational performance of the structure.

We acknowledge the assistance and cooperation of personnel of the Massachusetts Department of Public Works: Messrs. Willis Regan and Raymond Rochford, and of the Massachusetts Department of Environmental Quality Engineering, Division of Waterways: Messrs. John J. Hannon and Joseph Iagallo.

Also, we acknowledge the cooperation and assistance of personnel from the Worcester County Engineer's Office: Messrs. John O'Toole, Joseph Brazauskas, and Mr. Wallace Lindquist - recently retired from county service.

Further assistance was provided by personnel of the Massachusetts Electric Company: Messrs. Barry Huston, Denton Nichols, and Robert Jeniski; and Mr. Christopher D. Baker, Aide to the Millbury Planning Board.

- 2.2 Construction Records. There are no detailed construction records available other than the drawings included in Appendix B.
- 2.3 Operation Records. No detailed operation records are available, and there is no daily record kept of pool elevation or rainfall at the dam site.
- 2.4 Evaluation. The data acquired are considered adequate for this Phase I Inspection and Evaluation.

SECTION 3
VISUAL INSPECTION

3.1 Findings

- a. General. The Phase I inspection of the dam at Ramshorn Pond was performed on June 12, 1978. A copy of the inspection checklist is included in Appendix A. Periodic inspections of this dam by others have been made since 1924. A listing of these inspections is in Appendix B. Inspections were made by the Massachusetts Department of Public Works in 1972 and 1975--copies of their reports are included in Appendix B. In addition, early inspection reports were reviewed at the Worcester County Engineer's office.
- b. Dam. The dam is an earthfill embankment with a bituminous concrete roadway on the crest. The upstream face of the dam is riprap that shows signs of slumping. In addition, the top of the upstream slope has gullies caused by runoff from Dolan Road. Photograph C-4 in Appendix C shows the amount of deterioration on the upstream side of the crest and the buckling of the fence. It appears that an attempt to protect the slope and the fence was made by paving the slope with asphalt. The riprap at and below the present water surface appears to be in fair to good condition. Generally, the upstream face was clear of debris, with only small trees, brush and shrubs growing on it.

Erosion from surface runoff was also noted on the downstream face, particularly around the bridge over the spillway, and at the southern end near the right abutment. Further down the slope, a small seep exists that appears to be flowing at less than 1 gpm (gallon per minute) north to the outlet channel. Also at the toe of the right abutment, a small (8 by 12 foot) pool of water stands below a partially overgrown stone wall. The 1975 inspection report (Appendix B) suggests that this was once part of a stone box sluice, but no reference to it appears on the 1939 plans.

Seepage is also evident at the outlet head wall, and halfway down the downstream face between the spillway and gatehouse, where a very large area was moist and soft.

There is a large animal burrow on the downstream face and numerous chipmunk holes. The dense vegetation - weeds and bushes - growing on the downstream face of the dam prohibits a detailed inspection. Consequently, not all burrows or holes may have been detected.

- c. Appurtenant Structures. The outlet conduit is a 24-inch diameter metal pipe. The upstream end of the pipe is submerged, but according to the 1939 plans, extends 40 feet into the pond to a granite headwall. At the outlet end is a mortared masonry head wall, 8 feet high and in fair to good condition. The pipe appears to be flattened at the crown. Water from the outlet conduit discharges into a small pool that shows an accumulation of silt. From the pool, water normally flows downstream to join the water in the spillway channel. There is some evidence of a back-flow from the spillway channel to the pool.

The gatehouse structure is in fair condition, although the foot path to the entrance is very steep on the downstream face. Mr. Robert Jeniski of Massachusetts Electric unlocked the fence to the gatehouse and demonstrated that the rack and pinion mechanism was operable. There was, however, water and silt in the bottom of the gatehouse, and water leaking around the packing for the stem and casing. The gate valve was not visible and no further information concerning it is available.

The spillway headwall has minor cracks in the concrete (see Photographs C-1 and C-2, Appendix C). Two flashboards (bottom 11-inches high, top 8-inches high) were braced by five evenly spaced iron pins. There were gaps between the flashboards where water is spilling through. There is also minor erosion on the concrete at the southern end of the flashboards. The concrete under

the bridge is deteriorating, as are the concrete curbs on either side of the roadway. The spillway channel is in good condition, although there is some debris and vegetation in the channel. On the north side of the channel there is a 5-inch drain in the training wall from which water flows at an estimated 5 gpm. The source for this flow is unknown. There are small trees overhanging the lower earth spillway channel.

- d. Reservoir Area. The reservoir and drainage area is lightly populated with most of the development concentrating on the perimeter of the pond and along South Oxford Road. Work has begun on two new subdivisions off Dolan Road but the rest of the drainage area is chiefly wood and swampland with slopes ranging from 5 to 11 percent.
- e. Downstream Channel. Water from the spillway and the outlet conduit flows down a stream channel in a wooded area then into an open swamp. There is a second smaller dam at the mill pond near West Main Street that appears to be abandoned. From there, the stream flows through a stone channel under West Main Street and continues through woodland to Pondville Pond, about two miles downstream.

- 3.2 Evaluation. The above findings indicate signs of distress at the dam that require attention, particularly the riprap at the upstream face and the seepage areas on the downstream face. It is evident that the dam is not properly maintained and that deterioration will continue unless action is taken. Recommended measures to improve these conditions are stated in Section 7.

SECTION 4
OPERATING PROCEDURES

- 4.1 Procedures. Representatives from Massachusetts Electric Co. have informed us that there are no operating procedures at the dam since they have no use for the water from it. The outlet conduit is opened periodically in the fall and closed in the spring to regulate the water surface elevation for local residents upstream and downstream. At the time of the inspection, the outlet was closed.
- 4.2 Maintenance of Dam. The Owner does not have a definite maintenance and inspection program. However, we understand that several visits to the dam are made each year with particular attention paid to the condition of the spillway, flashboards and upstream face. In 1975, the Massachusetts Department of Public Works recommended erosional damage on the crest and upstream face be repaired to prevent continued deterioration. At the time of the inspection, it appeared that minor paving repairs had been made to alleviate the erosion along the fence on the upstream side of the crest.
- 4.3 Maintenance of Operating Facilities. The rack and pinion mechanism for opening the gate valve is operable. Information from the Worcester County Engineer's office is that repairs were made to the gate in 1963. However, there is leakage around the stem to the gate valve and standing water on the floor of the gatehouse.
- 4.4 Description of Any Warning System in Effect. There are no warning systems in effect at this dam. However, Mr. Robert Jeniski stated that in the event of hurricane flood warnings, the outlet conduit would be fully opened to lower the reservoir.
- 4.5 Evaluation. The program of inspection followed by the Owner should be expanded and made systematic, since this dam is in the high hazard category. Although some maintenance has been done, it appears to be limited to minor repairs.

SECTION 5

HYDRAULIC/HYDROLOGIC

5.1 Evaluation of Features

- a. Design Data. The Probable Maximum Flood (PMF) rate was determined to be 1,700 cfs per square mile. This calculation is based on the average drainage area slope of 6 percent, the pond-plus-swamp-area to drainage-area ratio of 17.5 percent, as well as the U.S. Army Corps of Engineers' guide curves for Maximum Probable Flood Peak Flow Rates (dated December 1977). Applying one-half the PMF to the 2.4 square miles of drainage area results in a calculated inflow test flood of 2,040 cfs. By adjusting this inflow for surcharge storage, the maximum discharge rate was established as 770 cfs, with a water surface at El 631.7 which is 0.2 foot above the lowest point on the dam crest.

A 100-year storm frequency is estimated to be about 600 cfs based on three different procedures as detailed in Appendix D. The spillway without flashboards can discharge this rate with the pond at El 630.8. The existing spillway without flashboards can discharge a flow of 750 cfs at El 631.5 which is the lowest point on the dam crest.

- b. Experience Data. Limited experience records are available for this dam. Past inspection reports state that the dam was overtopped in the 1938 flood and the dam crest had to be sandbagged. Also, records show that in the 1955 flood the water flowed about 4 feet above the spillway crest and did not overtop the dam.
- c. Visual Observations. The total dam structure consists of about 560 feet of earthen embankment, with a spillway section about 100 feet south of the northern end and a 24-inch outlet pipe passing under the dam about 250

feet south of the northern end. The outlet pipe discharge is regulated by a gatehouse which is recessed into the downstream face of the dam.

The spillway is about 18 feet wide, and is walled and paved for approximately 120 feet. The spillway crest is El 625.5 based on an assumed benchmark El 627 top of flashboards. The crest is raised some 19 inches by wooden flashboards, supported by vertical pipes. New flashboards and pins were installed in the spring of 1977. A steel walkway extends across the spillway opening about 2-1/2 feet above the flashboards and is apparently used to place and remove the flashboards. A highway bridge crosses the spillway just downstream of the crest and its bottom beams are about 5-1/4 feet above the crest or 3-3/4 feet above the top of the flashboards. The spillway slope includes three vertical drops and should discharge flows without any adverse backwater.

At the end of the paved spillway there is about a 2-foot drop to an earthen channel, which makes a 90 degree bend southward for 110 feet to another 90 degree bend easterly to join the original stream. The earthen channel is about 50 feet east of the toe of the dam, and is about 4 feet deep by 12 feet wide.

- d. Overtopping Potential. Overtopping of the dam is barely expected under an inflow test flood of 2,040 cfs; as noted previously, however, the records on overtopping indicate that the dam was overtopped during the 1938 flood but was not overtopped in 1955. Figures B-2 and B-3 in Appendix B show the dam was raised about 2 feet in 1939.

In the event of overtopping, complete failure of the dam could occur. A flood wave due to dam failure could cause significant loss of life and appreciable property damage.

The outflow discharge rate under failure has been calculated as about 10,500 cfs which produces a flood wave 8.7 feet high, at a point 3,200 feet downstream from the dam.

SECTION 6
STRUCTURAL STABILITY

6.1 Evaluation of Structural Stability

- a. Visual Observations. The evaluation of the structural stability of Ramshorn Pond Dam is based on the visual inspection conducted on June 12, 1978. As discussed in Section 3, Visual Inspection, there were several visible signs of distress.

Based on these observations, our judgment is that Ramshorn Pond Dam is a potential hazard. It is our opinion that static stability conditions are probably marginal and that conventional factors of safety do not exist.

It is recommended that a more detailed investigation be initiated to evaluate the seepage and pool of water at the downstream toe of the dam.

- b. Design and Construction Data. Discussions with the Owner, Town, County, and State personnel indicate that there are no plans, specifications, or computations relative to the design, construction, or repairs of this dam other than the three drawings attached as Figures B-1, B-2, and B-3 in Appendix B. Information on the type, shear strength, and permeability of the soil and/or rock materials of the dam embankment does not appear to exist.

It was learned that this dam was originally built in 1825, probably of local soil or rock materials. As discussed in Section 1, Paragraph 1.2.h, changes were made in the dam in 1873, 1915, and 1939. As noted in Figure B-2, the cutoff consists of chestnut planking driven along the centerline and for a distance of 10 feet either side. The fill was placed in layers and puddled.

- c. Operating Records. There is no evidence of instrumentation of any type in Ramshorn Pond Dam, and there is nothing to indicate that

any instrumentation was ever installed in this dam. The performance of this dam under prior loading can only be inferred by previous records and physical evidence at the site.

- d. Postconstruction Changes. There are no as-built drawings for Ramshorn Pond Dam. There have been significant modifications to the original dam since 1825 as noted in discussions above. Changes to the dam in the spring of 1977 consisted of new flashboards and pins. Also it appears that some minor paving was done on the upstream to repair washout and to prevent further erosion.
- e. Seismic Stability. This dam is located in Seismic Zone 2. Since static stability conditions are marginal, the dam is particularly vulnerable in the event of an earthquake.

SECTION 7

ASSESSMENT, RECOMMENDATIONS, AND REMEDIAL MEASURES

7.1 Dam Assessment

- a. Condition. Due to its age, Ramshorn Pond Dam was neither designed nor constructed according to current approved state-of-the-art methods. Based on the visual inspection at the site, and the limited engineering data available, there are areas of concern which must be corrected to assure the continued performance of this dam. Generally, the dam is considered to be in fair condition, however, as noted previously, there were several signs of distress observed at the site: slight seepage at the downstream toe of the dam, a pool of water on the downstream toe, erosion on the upstream face and downstream face of the dam, small trees and brush on the dam, accumulation of debris in the spillway channel, slumped riprap on the upstream face, leakage around the gate valve stem, and a large animal burrow and numerous chipmunk holes on the downstream face.

Hydraulic analyses indicate the existing spillway without flashboards can discharge a flow of 770 cfs at El 631.7, which is the average top of the dam. An inflow test flood of 2,040 cfs will overtop the lowest point on the main dam by about 0.2 feet. Since previous records at this site indicate the dam at its present elevation was not overtopped in the 1955 floods, it is unlikely that this is a serious potential hazard. However, it is not known what the pond elevation was prior to the storm. Possibly the pond was at a seasonal low elevation thereby providing sufficient storage to lessen the effects of the rainfall. Also the pond level may have been intentionally lowered because of the impending storm. Further, it is not known whether there were any flashboards on the dam at the time of the storm.

- b. Adequacy of Information. The information available is such that the assessment of the condition of the dam must be based primarily on the visual inspection and the past operational performance of the structure.
- c. Urgency. The recommendations outlined below should be implemented within one to two years after receipt of the Phase I Inspection Report.
- d. Need for Additional Information. Additional investigations to further assess the adequacy of the dam and appurtenant structures are outlined below in section 7.2 Recommendations.

7.2 Recommendations

In view of the concerns on the continued performance of this dam, it is recommended that the Owner employ a qualified consultant to

- a. evaluate the seepage and the pool of water at the downstream toe,
- b. conduct a detailed hydraulic analysis and evaluate the need to increase spillway capacity, redesign the flashboards, and raise the dam crest.

The recommendations on repairs and maintenance procedures are stated below under 7.3 Remedial Measures.

7.3 Remedial Measures

- a. Alternatives. An alternative to the recommendations listed above and the maintenance procedures itemized below would be to drain the reservoir and breach or remove the dam.
- b. Operation and Maintenance Procedure. The dam and appurtenant structures are not adequately maintained. It is recommended that the Owner accomplish the following items.
 - (1) repair the eroded upstream and downstream slopes

- (2) replace and/or repair riprap
- (3) repair the leaking gate valve stem
- (4) remove brush and trees from the dam
- (5) clear all debris from the spillway
- (6) fill in all animal burrows
- (7) institute a definite plan for surveillance and a warning system during periods of unusually heavy rains and/or runoff
- (8) implement a systematic program of inspection and maintenance. As a minimum the inspection program should consist of a monthly inspection of the dam and appurtenances and supplemented by additional inspections during and after severe storms. All repairs and maintenance should be undertaken in accordance with all applicable State regulations.

APPENDIX A
PERIODIC INSPECTION CHECKLIST

PERIODIC INSPECTION

PARTY ORGANIZATION

PROJECT Ramshorn Pond Dam

DATE 6/12/78

TIME 8:00am → 5:00 pm

WEATHER Sunny, 75 → 85° F

W.S. ELEV. 627 U.S. 609.9 D.N.S.

Assumed benchmark elevation 627
top of flashboards

PARTY:

- | | |
|-------------------------|-----------|
| 1. <u>Ed Greco</u> | 6. _____ |
| 2. <u>Susan Pierce</u> | 7. _____ |
| 3. <u>Lyle Branagan</u> | 8. _____ |
| 4. _____ | 9. _____ |
| 5. _____ | 10. _____ |

PROJECT FEATURE

INSPECTED BY

REMARKS

- | | | |
|--------------------|----------------------|--|
| 1. <u>Dam</u> | <u>Ed Greco</u> | |
| 2. <u>Spillway</u> | <u>Lyle Branagan</u> | |
| 3. _____ | | |
| 4. _____ | | |
| 5. _____ | | |
| 6. _____ | | |
| 7. _____ | | |
| 8. _____ | | |
| 9. _____ | | |
| 10. _____ | | |

PERIODIC INSPECTION CHECK LIST

PROJECT Ramshorn Pond Dam

DATE 6/12/78

PROJECT FEATURE Dam

NAME Ed Greco

DISCIPLINE Geotechnical

NAME _____

AREA EVALUATED	CONDITIONS
<u>DAM EMBANKMENT</u>	
Crest Elevation	varies from 631.5 to 635.61
Current Pool Elevation	627
Maximum Impoundment to Date	unknown
Surface Cracks	cracks in pavement at crest
Pavement Condition	fair to good except at upstream face
Movement or Settlement of Crest	pavement at crest slightly irregular
Lateral Movement	none visible
Vertical Alignment	relatively flat
Horizontal Alignment	relatively straight
Condition at Abutment and at Concrete Structures	earth embankment at abutment - condition good; trees on ups face of right and left abutment
Indications of Movement of Structural Items on Slopes	fence on upstream face in poor condition
Trespassing on Slopes	woodchuck hole on right embankment chipmunk hole in center of dam
Sloughing or Erosion of Slopes or Abutments	erosion on upstream slope
Rock Slope Protection - Riprap Failures	upstream face in poor condition erosion on road, fence settling
Unusual Movement or Cracking at or near Toes	several large boulders at toe, 100 feet south of gatehouse
Unusual Embankment or Downstream Seepage	dampness on slope, 50 feet south of spillway channel (see NOTE, page A-3)
Piping or Boils	none visible
Foundation Drainage Features	unknown
Toe Drains	unknown
Instrumentation System	unknown

PERIODIC INSPECTION CHECK LIST

PROJECT Ramshorn Pond

DATE 6/12/78

PROJECT FEATURE Intake

NAME Ed Greco

DISCIPLINE Geotechnical

NAME _____

AREA EVALUATED	CONDITION
<u>OUTLET WORKS - INTAKE CHANNEL AND INTAKE STRUCTURE</u>	
a. Approach Channel	stone retaining walls *
Slope Conditions	not visible
Bottom Conditions	" "
Rock Slides or Falls	" "
Log Boom	" "
Debris	" "
Condition of Concrete Lining	" "
Drains or Weep Holes	" "
b. Intake Structure	stone headwall *
Condition of Concrete	not visible
Stop Logs and Slots	" "

* Based on 1939 drawing showing plan of Dam No. 30-21

FROM PAGE A-2

NOTE: Downstream seepage noted; small (8x10 ft) pool of water at toe of right abutment; apparent stone headwall at head of seep.

Erosion of road at right abutment, down slope to toe; small seep at bottom of erosion gully, flow 1 gpm.

PERIODIC INSPECTION CHECK LIST

PROJECT Ramshorn Pond DATE 6/12/78
 PROJECT FEATURE Outlet NAME Ed Greco
 DISCIPLINE Geotechnical NAME _____

AREA EVALUATED	CONDITION
* <u>OUTLET WORKS - TRANSITION AND CONDUIT</u>	
General Condition of Concrete	n/a
Rust or Staining on Concrete	"
Spalling	"
Erosion or Cavitation	"
Cracking	"
Alignment of Monoliths	"
Alignment of Joints	"
Numbering of Monoliths	"

* Gatehouse located on downstream slope: small wooden shed sits on circular dry stone well 7.5 ft diameter and 6.5 ft deep, water and silt in bottom.

Rack and pinion gear with handwheel, some flow visible from packing around stem and casing.

Gate operated smoothly - water flowed from outlet pipe into channel.

When outlet gate valve is closed, there are 18 threads visible on the gate valve stem above the frame. Mr. Jeniski turned the handwheel to partially open gate valve, and 22 threads were visible on the stem. Mr. Jeniski stated that the gate valve would be fully opened when 24 threads were visible.

PERIODIC INSPECTION CHECK LIST

PROJECT Ramshorn Pond DATE 6/12/78
 PROJECT FEATURE Outlet wall NAME Ed Greco
 DISCIPLINE Geotechnical NAME _____

AREA EVALUATED	CONDITION
<u>OUTLET WORKS - OUTLET STRUCTURE AND OUTLET CHANNEL</u>	Mortared stone headwall : 24-inch cast iron pipe , top bent. Outlet partially covered, silt accumulating in stilling pool.
General Condition of Concrete	
Rust or Staining	none visible
Spalling	stone in fair to good condition
Erosion or Cavitation	none visible
Visible Reinforcing	none
Any Seepage or Efflorescence	slight seep at headwall , south side
Condition at Joints	mortar fair to good
Drain Holes	none visible
Channel	silt accumulation
Loose Rock or Trees Over- hanging Channel	small trees and brush
Condition of Discharge Channel	fair - brush and silt accumulation

PERIODIC INSPECTION CHECK LIST

PROJECT Ramshorn Pond
 PROJECT FEATURE Spillway
 DISCIPLINE Hydraulics

DATE 6/12/78
 NAME Lyle Branagan
 NAME Ed Greco

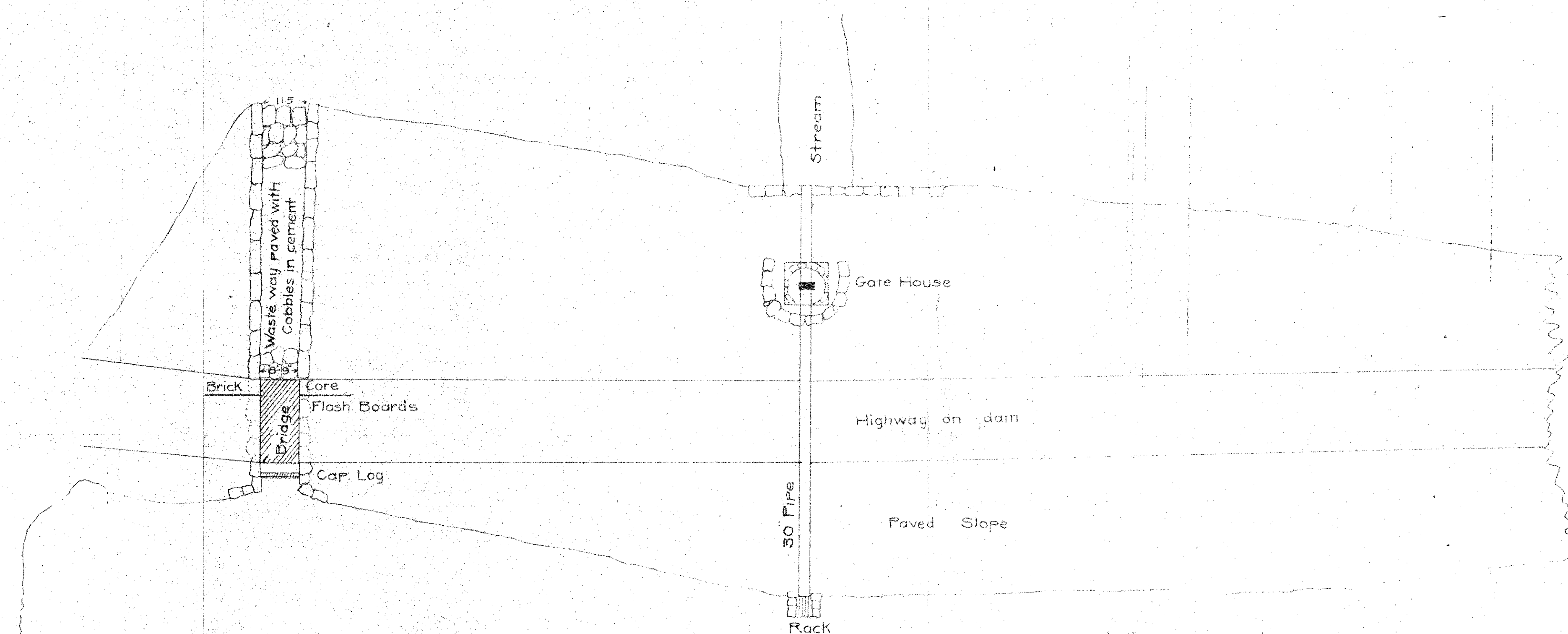
AREA EVALUATED	CONDITION
<u>OUTLET WORKS - SPILLWAY WEIR, APPROACH AND DISCHARGE CHANNELS</u>	Concrete approach in front of flashboards *
a. Approach Channel	Stone and concrete headwall
General Condition	fair to good
Loose Rock Overhanging Channel	none
Trees Overhanging Channel	none
Floor of Approach Channel	clear - no obstructions
b. Weir and Training Walls	Concrete and stone - walkway above bridge over spillway has concrete curbs in poor condition - probably salt
General Condition of Concrete	fair to good
Rust or Staining	none except bridge
Spalling	minor, except on bridge
Any Visible Reinforcing	only on bridge - rusted
Any Seepage or Efflorescence	
Drain Holes	none
c. Discharge Channel	** mortared stone with 2-ft high walls
General Condition	fair to good
Loose Rock Overhanging Channel	none
Trees Overhanging Channel	small trees
Floor of Channel	debris and vegetation
Other Obstructions	none

* Two flashboards - 19" total, 5 1-3/8-inch supporting pipes; gap between boards at right end allows water to flow through; minor erosion of concrete also.

** 6-inch drain in wall below stepped channel on north side; flow about 5 gpm - source unknown

APPENDIX B

	<u>Page</u>
Dam Plan dated September 6, 1892 - Figure B-1	In Pocket
Plan of Dam and Profile, filed August 1939 - Figure B-2	In Pocket
Plan of Spillway Elevation and Section Through Dam, filed August 1939 - Figure B-3	In Pocket
Previous Inspections (Partial Listing)	B-4
Inspection Report from Massachusetts Department of Public Works, February 1972	B-6
Letter Report to Massachusetts Electric Company	B-7
Inspection Report from Massachusetts Department of Public Works, October 1975	B-9



Charles Allen
Engineer

FIGURE B-1

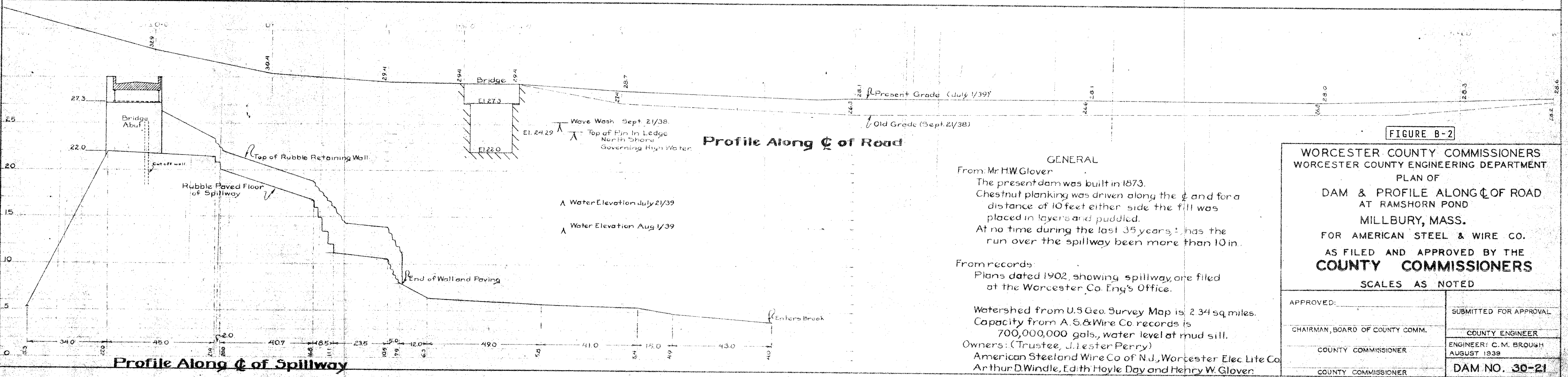
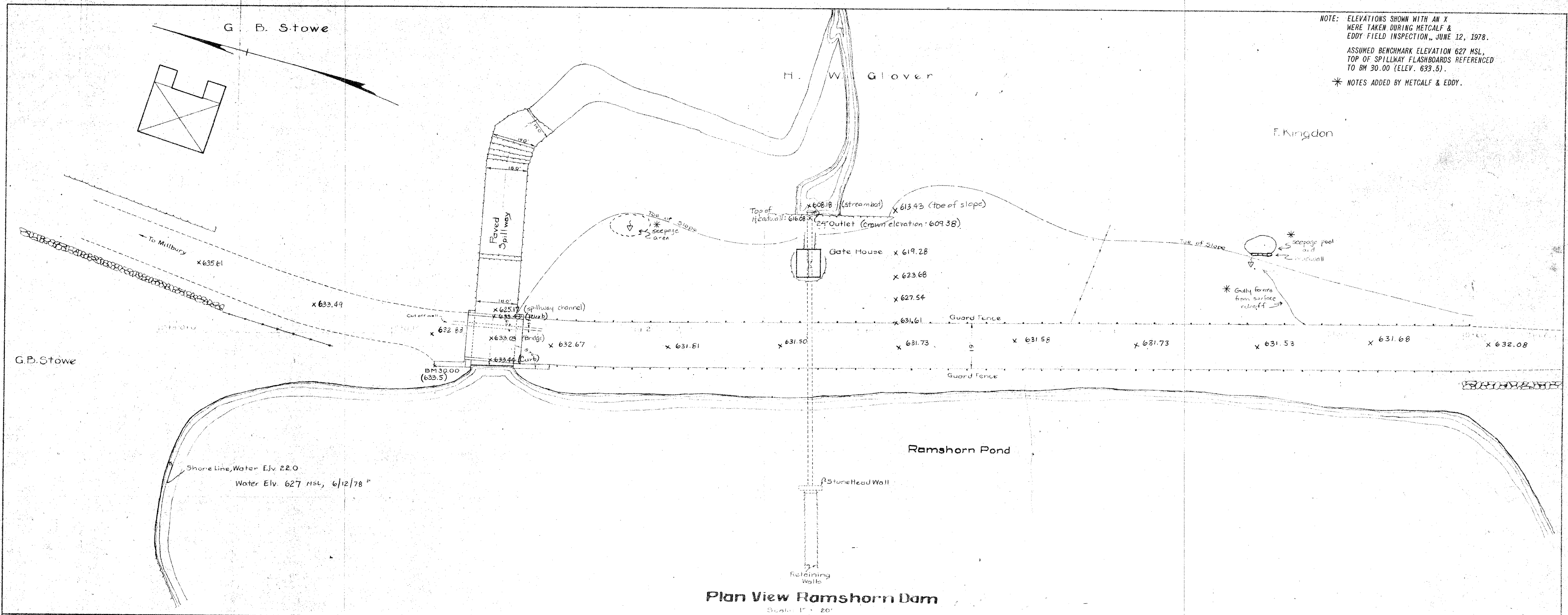
WORCESTER COUNTY COMMISSIONERS
WORCESTER COUNTY ENGINEERING DEPARTMENT
PLAN OF
DAM
AT RAMSHORN POND
MILLBURY, MASS.
FOR THE RAMSHORN POND CO.
AS FILED AND APPROVED BY THE
COUNTY COMMISSIONERS
SEPT. 6, 1892
JUNE MEETING DOCKET 152
SCALE: 1 IN. = 20 FT.

TRACED BY: *L.O. Marden* 2-21-36
TRACING CHECKED BY: *L.O. Marden* 2-23-36

DAM NO. 30-21

L.O. Marden COUNTY ENGINEER

A TRUE COPY
ATTEST: *William C. Bowen*
CLERK OF COURTS *March 10, 1936*



GENERAL
From Mr. H. W. Glover
The present dam was built in 1873. Chestnut planking was driven along the C and for a distance of 10 feet either side the fill was placed in layers and puddled. At no time during the last 35 years has the run over the spillway been more than 10 in.

From records:
Plans dated 1902, showing spillway, are filed at the Worcester Co. Eng's Office.

Watershed from U.S. Geo. Survey Map is 2.34 sq. miles. Capacity from A. S. & Wire Co. records is 700,000,000 gals., water level at mud sill.

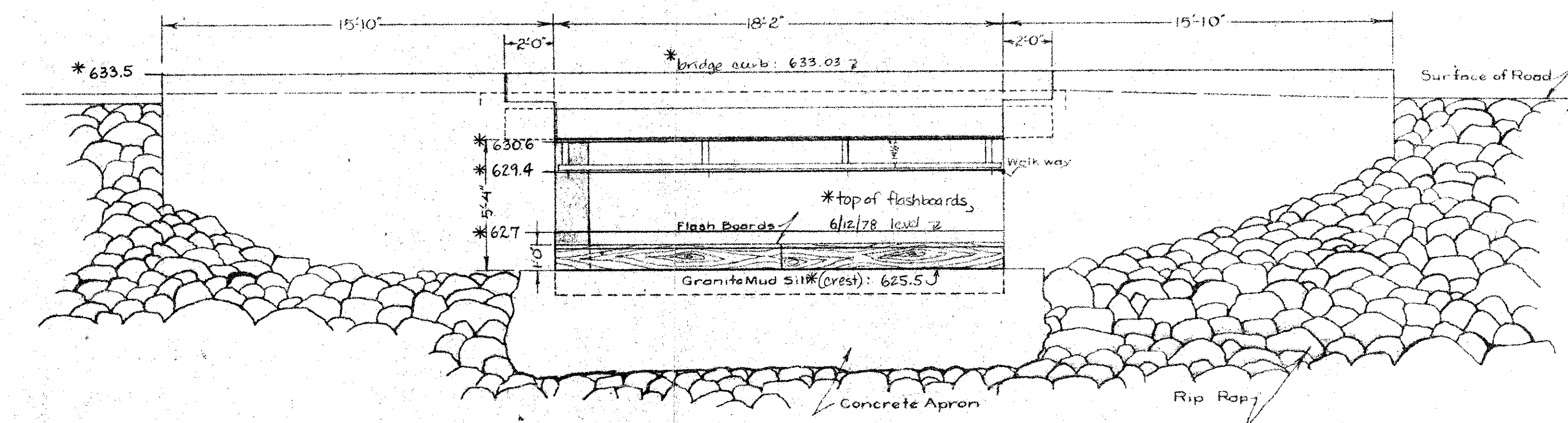
Owners: (Trustee, J. Lester Perry)
American Steel and Wire Co. of N.J., Worcester Elec. Lite Co.
Arthur D. Windle, Edith Hoyle Day and Henry W. Glover

FIGURE B-2

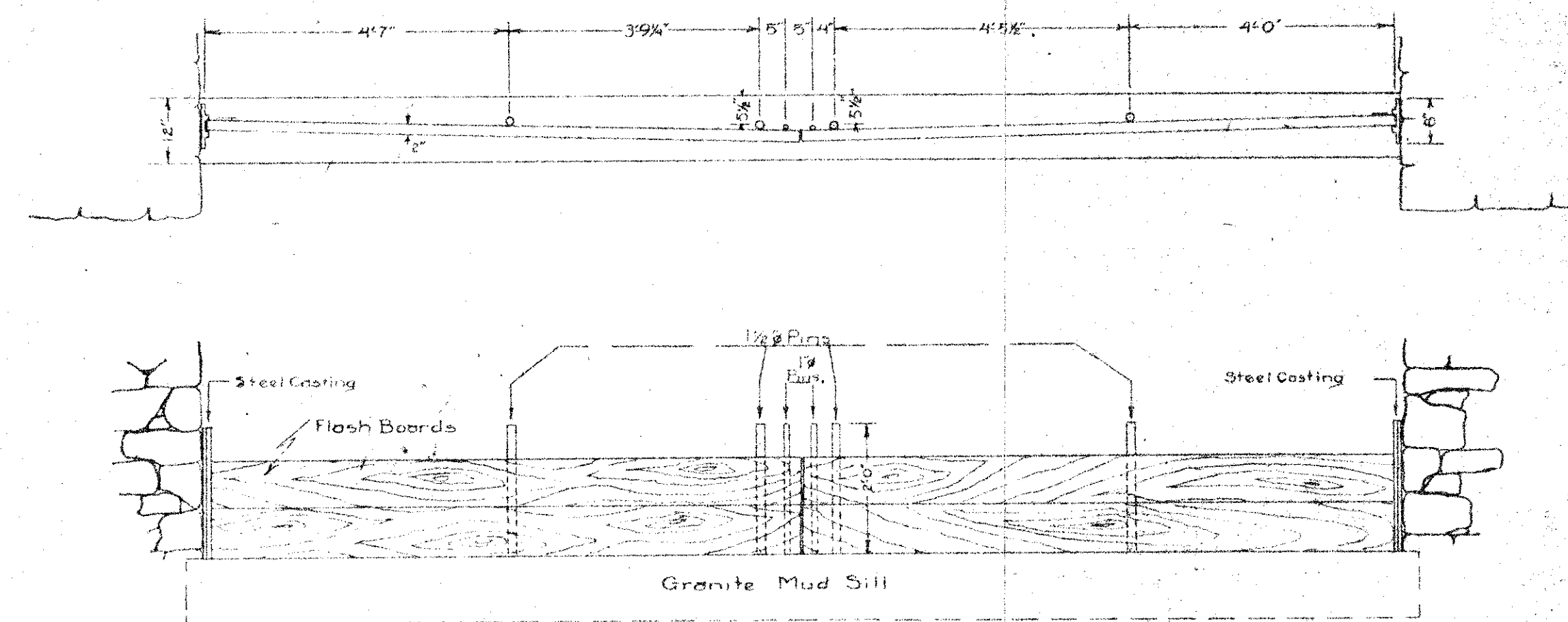
WORCESTER COUNTY COMMISSIONERS
WORCESTER COUNTY ENGINEERING DEPARTMENT
PLAN OF
DAM & PROFILE ALONG C OF ROAD
AT RAMSHORN POND
MILLBURY, MASS.
FOR AMERICAN STEEL & WIRE CO.
AS FILED AND APPROVED BY THE
COUNTY COMMISSIONERS
SCALES AS NOTED

APPROVED:	SUBMITTED FOR APPROVAL
CHAIRMAN, BOARD OF COUNTY COMM.	COUNTY ENGINEER
COUNTY COMMISSIONER	ENGINEER: C. M. BROUGH AUGUST 1938
COUNTY COMMISSIONER	DAM NO. 30-21

NOTE: THIS DAM RESULT BEFORE PLAN RECEIVED.



**Elevation of Spillway
Pond Side**
Scale: 1/4" = 1 foot



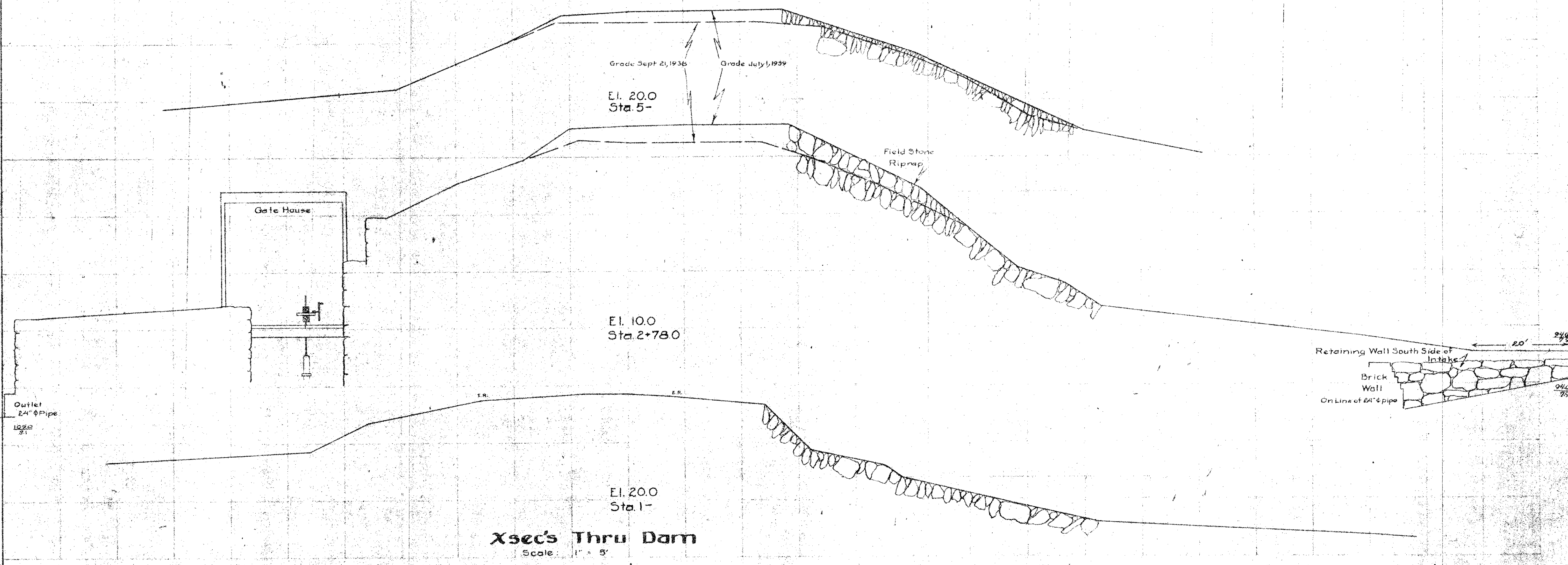
Plan and Elevation of Flashboards
Scale: 1/2" = 1'

- * FLASHBOARD DETAILS NOT AS SHOWN. THE FOLLOWING MODIFICATIONS WERE NOTED, JUNE 12, 1978:
- 2 FLASHBOARDS - ONE 8-INCH (UPPER), ONE 11-INCH (LOWER)
 - 5 PINS - 1 3/8-INCH IRON PIPES EVENLY SPACED ALONG FLASHBOARDS

NOTE: ELEVATIONS ON SPILLWAY TAKEN DURING METCALF & EDDY FIELD INSPECTION, JUNE 12, 1978.

ASSUMED BENCHMARK ELEVATION 627 MSL, TOP OF SPILLWAY FLASHBOARDS REFERENCED TO BM30.00 (ELEV. 633.5).

* NOTES AND ELEVATIONS ADDED BY METCALF & EDDY.



Xsec's Thru Dam
Scale: 1" = 5'

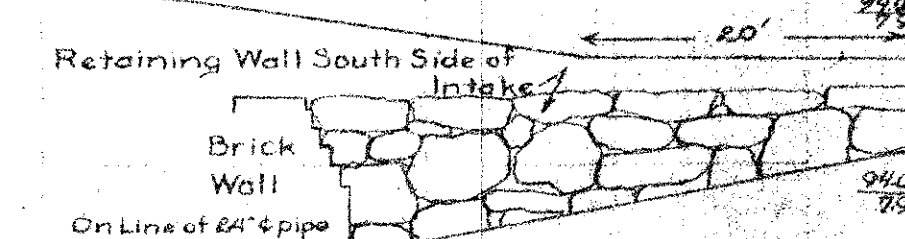


FIGURE B-3

WORCESTER COUNTY COMMISSIONERS
WORCESTER COUNTY ENGINEERING DEPARTMENT
PLAN OF
SPILLWAY ELEV. & SECTION THRU DAM
AT RAMSHORN POND
MILLBURY, MASS.
FOR AMERICAN STEEL & WIRE CO.
AS FILED AND APPROVED BY THE
COUNTY COMMISSIONERS
SCALES AS NOTED

APPROVED	SUBMITTED FOR APPROVAL
CHAIRMAN, BOARD OF COUNTY COM.	COUNTY ENGINEER
COUNTY COMMISSIONER	ENGINEER: C. M. BROUGH AUGUST 1939
COUNTY COMMISSIONER	DAM NO. 30-21

TOWN OR CITY

Millbury

DECREE NO.

RAMSHORN POND (M.T.H.)

152

PLAN NO.

STORAGE POND

DAM NO.

152 21

LOCATION

West Millbury - Ramshorn Pond.

C. C. DOCKET NO.

DESCRIPTION OF DAM

Type Hy Emb. 2:1 Slopes - riprap El. 100'
 Length 400'
 Height 30'
 Thickness top abt = 21' emb = 21'
 " bottom 80'
 Downstream Slope 2:1
 Upstream " 2:1
 Length of Spillway Riprap
 Size of Gates 30" Iron El. 70.5 Depth = 95.5 ft. 18'
 Location of Gates 100' East Spillway
 Flashboards used (NO BOARDS ON SPILLWAY) 57 Yes
 Width Flashboards or Gates El. 95.5 18'
 Dam designed by 24'
 " constructed by
 Year constructed

DESCRIPTION OF RESERVOIR & WATERSHED

Name of Main Stream Ramshorn Brook
 " " any other Streams
 Length of Watershed
 Width " "
 Is Watershed Cultivated
 Percent in Forests
 Steepness of Slope
 Kind of Soil Rocky
 No. of Acres in Watershed 1600 Acres 2.26 Sq. M.
 " " " Reservoir 700 acres at spillway level
 Length of Reservoir 796 feet - 24" flashboards
 Width " "
 Max Flow Cu. Ft. per Sec.
 Head or Flashboards-Low Water
 " " " High "

GENERAL REMARKS

J. Lester Perry
 Ramshorn Pond Co. - Am. Steel & Wire
 Inspected: Sept. 20, 1924 - L. O. Marden.
 Mass. Electric
 " : Nov. 15, 1928
 " : Sept. 29, 1932
 " : May 13, 1937 K. M. Finlayson
 " : Oct. 18, 1938 " "
 " : Sept. 23, 1938 W. O. Lindquist
 Measured : April 26, 1939 - L. H. Searly M. F. Hunt
 (OVER)

GENERAL REMARKS

Trustee - Wore.
 Co. Docket #152. Meeting, June - 1892. Filed, Sept. 6, 1892
 Traced by: L. C. Farrar - Feb. 21, 1936.
 Checked by: L. O. Marden - Feb. 27, 1936.
 Attested by: William C. Bowen, C. of C. Mar. 10, 1936
 Charles Allen - Engineer.
 Patrol: March 1, 1939 - W. O. Lindquist.
 Inspected: Dec. 12, 1940 - L. H. Spafford
 St. John - Herkholz.
 Inspected: Nov. 26, 1941 - F. M. Crockett
 L. O. Marden
 (OVER) 2 - Library Bureau 10-92260

PREVIOUS INSPECTIONS (PARTIAL LISTING)

COPY OF INSPECTION CARD ON FILE AT THE MASSACHUSETTS
 DEPARTMENT OF PUBLIC WORKS, DISTRICT OFFICE, WORCESTER.

Inspected: Dec. 9, 1942. J.A. Herholz
 Dec. 14, 1945 W.O. Lindquist
 Mar. 25, 1963 W.O.L. - G.J.C.

Vol. 8, Pg 470 - Dec. 1825 - Accepted by Court
 proposed dam for Blackstone Canal Corp
 Ramshorn Pond on land of Stephen
 Blanchard, Elisha Jacobs, et al.
 Ramshorn Pond Co. Association
 85% of the Rights of the Am. Steel
 & Wire Co. taken over by the Mass.
Electric Association.

MASS ELECTRIC COMPANY
 939 SOUTHBRIDGE ST.
 WORCESTER, MASS.

PREVIOUS INSPECTIONS (PARTIAL LISTING)

**COPY OF INSPECTION CARD ON FILE AT THE MASSACHUSETTS
 DEPARTMENT OF PUBLIC WORKS, DISTRICT OFFICE, WORCESTER.**

INSPECTION REPORT & DATA FOR DAMS

Owner: MASS ELECTRIC COMPANY

His Address: 939 South Street, Worcester, Mass

Function of Dam: SPILLWAY POND

Location & Access: DOLAN RD MILLBURY

USGS Quad. 1400C, South Lat. 42° 09' 45" Long. 71° 13' 30"

Drain. Ar.: 2.24 Sq. Mi. Ponds: ac. Res. @ dam:

Character of D.A.:

Estimated

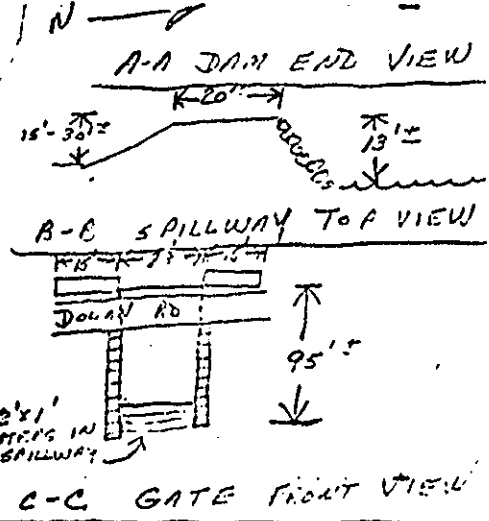
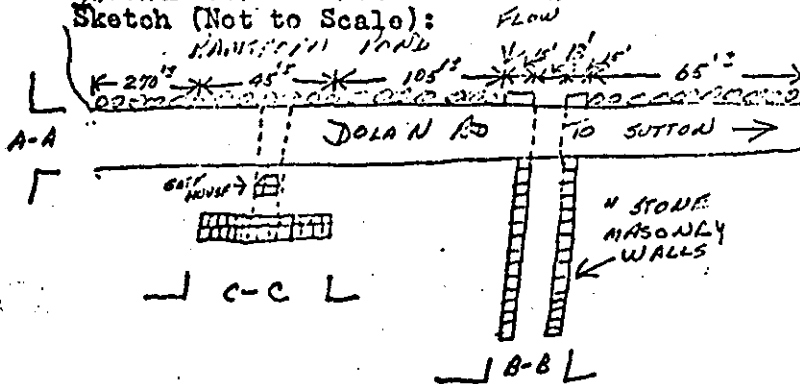
Discharge:

Capacity:

General Description of Dam and Discharge Control:

DOLAN ROAD IS THE DAM. WATER SIDE OF DAM IS RIP RAPPED
DOWNSTREAM SIDE EARTHEN SLOPE. SLOPES ARE APPROX. 2:1. NO
FLASHBOARDS ON SPILLWAY. UNKNOWN SIDE SIDE, BUT 8" 14 34"
METAL PIPES FOR OUTLET.

Sketch (Not to Scale):



Remarks and Recommendations:

Date

2/2/72

By

E. MURPHY
R. NICHOLSON

Comment

Dam No. 30-21

Town: MILLBURY

Stream: RAMSHORN BROOK

Pond: RAMSHORN POND

Date: 2/2/72

By: R. Nicholson

CONDITION RATING

Structural: GOOD

Hydraulic: 18' 13' 4 2' 10"

General: GOOD

PRIORITY: NONE

Dam No. 3-14-186-21

November 6, 1975

Massachusetts Electric Company
932 Southbridge Street
Worcester, Massachusetts

RE: Inspection - Dam #3-14-126-21
Millbury
Marshorn Pond Dam

Gentlemen:

As requested by representatives from the Town of Millbury, a visual inspection of the above dam was conducted by an engineer from the Massachusetts Department of Public Works on October 16, 1975. Our records indicate that the Massachusetts Electric Company is the owner. Will you please notify this office if this information is not current.

The inspection was made in accordance with Chapter 253 of the Massachusetts General Laws, as amended by Chapter 595 of the Acts of 1970 (Dams-Safety Act).

The results of the inspection indicate that repairs and/or maintenance are needed. The following conditions were noted that require attention:

1. At the time of inspection the gate house was locked and it could not be determined if the gate is operative. The gate should be checked and repaired or replaced if necessary.
2. The riprap blanket along the upstream embankment of the dam (down face) is in generally poor condition with several slumped areas. This appears to be the result of wave action and surface runoff and the lack of an active maintenance program. Channelization of surface runoff (paved waterways) and realigning the riprap or the placing of additional stone is recommended.
3. Remove the growth of brush and trees from the embankment of the dam.

November 6, 1975


4. There is a burrow hole and some minor surface erosion which should be filled with suitable material, properly compacted and graded.
5. At the downstream toe near the southerly end of the dam there is a pool of standing water about 8 ft. in diameter and several feet deep adjacent to what appears to be a stone headwall. The cause of this pool could not be determined but an investigation followed by the necessary corrective action is recommended.
6. The 24" sluiceway (with full flow at the time of inspection) was scouring the downstream channel and embankment slope. Some type of stilling basin, energy dissipator or riprap blanket should be constructed to correct this problem.
7. Some of the capstones from the spillway sidewalls are missing and should be replaced. The spillway floor has brush growing through the joints which should be cleaned and sealed. The north sidewall at the downstream end should be repaired.

It is our understanding that a transfer of ownership of the dam is contemplated. It is recommended that the services of a Registered Professional Civil Engineer experienced in the design, maintenance and construction of dams be obtained and an in-depth inspection-evaluation be made.

We call these conditions to your attention so that prompt action may be made to correct these deficiencies. Once the repairs are made a regular program of inspection and maintenance should be established. If we may be of assistance, please contact us. With any correspondence please include the number of the dam as indicated above.

Very truly yours,

ROBERT T. TIERNEY, P.E.
Chief Engineer


cc: Millbury Board of Selectmen
Hayden, Harding & Buchanan, Inc.
Ramsburn Association
J. J. Lyons
W. Hayden

DESCRIPTION OF DAM

DISTRICT 3Submitted by W. REGANDam No. 3-14-186-21Date 10/20/75City/Town MillburyName of Dam RAMSHORN POND1. Location: Topo Sheet No. 21B (Worcester So. Quad)

Provide 8 1/2" x 11" in clear copy of topo map with location of Dam clearly indicated.

2. Year built: 1873 Year/s of subsequent repairs 19393. Purpose of Dam: Water Supply _____ Recreational & Road Emb.
Irrigation _____ Other _____4. Drainage Area: 2.33 sq. mi. _____5. Normal Ponding Area: 120 ± acres; Ave. depth 17 1/2' ± (Computed W.R.)
(When W.S. Elev. = Spillway Crest) (When W.S. Elev. = Spillway Crest) acre ft. Crd.6. No. and type of dwellings located adjacent to pond or reservoir
_____ i.e. summer homes, etc. 90 ± Residences7. Dimensions of Dam: Length 500' ± Max. Height 30' ±

Slopes: Upstream Face _____

Downstream Face _____

Width across top _____

} See ATTACHED
SKETCH

8. Classification of Dam by Materials:

Earth ☒Conc. Masonry ☒Stone Masonry ☒

Timber _____

Rockfill _____

Other RIP RAP U.S. FAC

9. A. Description of present land usage downstream of dam:

80 % rural;20 % urban.Residential & Light Indust

* B. Is there a storage area or flood plain downstream of dam which could accommodate the impoundment in the event of a complete dam failure? yes _____ no _____

There is A Large amount of Storage between Dolan Rd. & Millbury
 ③ IN The meadows N. & S. of Carleton St. However Drainage Ar.
 and Impounded Volume is large and Dolan Rd (where a
 Forms The Dam) and Millbury St would Wash out. Heavy
 Residential Property Damage @ Millbury St is Certain

10. Risk to life and property in event of complete failure.

No. of people Remote Threat of loss of life Vic. Millbury St.
No. of homes > 10
No. of Businesses -
No. of Industries - Type -
No. of utilities All utilities over & under Dolan Rd. & Millbury St. Type -
Railroads 1 R.R. Line 3 1/2 mi. Downstream
Other dams Auburn # 4 (Pondville Pond)
Other Rte. 20 is 3 1/2 mi. D.S.

11. Attach Sketch of dam to this form showing section and plan on 8 1/2" x 11" sheet.

12. How to Locate: W. B. on Rte. 20 (Auburn), Turn LT. onto Elm St. 2 1/4 ± mi. beyond Wore. Line. Travel 1 1/2 ± mi. To Oxford Rd. Intersection (Millbury). Turn LT. onto Dolan Rd., Travel 1 1/2 ± mi. To Dam Which is Formed by Dolan Rd. Emb.

INSPECTION REPORT - DAMS AND RESERVOIRS

1. Location: City/Town Millbury Dam No. 3-14-186-21
 Name of Dam RAMSHORN POND Inspected by REGAN, RIZKALLA
 Date of Inspection 10/16/75

2. Owner/s: per: Assessors _____ Prev. Inspection ☒
 Reg. of Deeds _____ Pers. Contact _____

1. MASS. Electric Co. 939 Southbridge St. Worcester, MASS.
 Name COPY T. St. & No. _____ City/Town State Tel. No. _____

2. Board of Selectmen, Millbury, MASS.
 Name Pauline Rock St. & No. _____ City/Town State Tel. No. _____

Abutting Property Owners } 3. RAMSHORN Association c/o R.F.D. #2, GRIGGS RD., Sutton, MASS.
 Name _____ St. & No. _____ City/Town State Tel. No. _____

3. Caretaker (if any) e.g. superintendent, plant manager, appointed by absentee owner, appointed by multi owners.

Name: _____ St. & No.: _____
 City/Town: _____ State: _____ Tel. No.: _____

4. No. of Pictures taken _____

5. Degree of Hazard: (if dam should fail completely)*

1. Minor _____ 2. Moderate ☒
 3. Severe _____ 4. Disastrous _____

* This rating may change as land use changes (future development)

6. Outlet Control: Automatic _____ Manual ☒
 Operative APPARENTLY yes; _____ No.

Comments: GATE SHED LOCKED - APPURTENANCES NOT ACCESSIBLE FOR INSPECTION

7. Upstream Face of Dam: Conditions:

1. Good _____ 2. Minor Repairs _____
 3. Major Repairs ☒ 4. Urgent Repairs _____

Comments: RIP RAP FACE TOP 1/2 IN POOR CONDITION
BOTTOM 1/2 IN POOR TO FAIR CONDITION

Top 1/2 has slid downward @ various locations
Edge of Rd. Failing; Longitudinal Cracks in Edge
of Rd 2'± From Edge indicate S.G. material Slumping
Downslope & Progression of Failure Very likely
(Remove growth of trees & brush)

8. Downstream Face of Dam:

Condition: 1. Good _____ 2. Minor Repairs _____
 3. Major Repairs ✓ Possibly Indicated 4. Urgent Repairs _____

Comments: Heavy growth of trees & brush should be removed.
 1 large ANIMAL Burrow Noted, minor Amount of Surface Erosion
 at a few locations; Bottom $\frac{1}{2}$ - $\frac{1}{3}$ of Slope (and Areas beyond Tie)
 Saturated at various locations

9. Emergency Spillway:
Principal

Condition: 1. Good _____ 2. Minor Repairs ✓
 3. Major Repairs _____ 4. Urgent Repairs _____

Comments: Some Sidewall Capstone missing (Replace), Remove growth
 and overburden from Top of Sidewalls, Remove brush growing in
 Spillway Floor (Seal open joints with Cem. grout), Repair damage to
 N. Sidewall @ D.S. Extremity.

10. Water Level at time of inspection: $3\frac{1}{2} \pm$ ft. above _____ below ✓

top of dam _____ principal spillway Crest

other _____

11. Summary of Deficiencies Noted:

Growth (Trees and Brush) on Embankment ✓

Animal Burrows and Washouts one Animal Burrow Noted

Damage to slopes or top of dam ✓

Cracked or Damaged Masonry Minor Damage - Spillway

Evidence of Seepage ✓

Evidence of Piping See (12)

Erosion ✓

Leaks See (12)

Trash and/or debris impeding flow Minor Amount of Debris in Spill

Clogged or blocked spillway See Above " " Brush in Spillway

Other RIP RAP U.S. FACE IN Poor Condition

12. Remarks & Recommendations: (Fully Explain)

This inspection was initiated at the Request of a Consultant (Hayden, Harding, and Buchanan) retained by The Town of Millbury To Advise The Town regarding Possible Acquisition of The dam From Mass. Electric. Another group ~~possibly~~ interested in The Acquisition of This dam is The Ramshorn Association (Property owner Abutting The Impoundment).

Any Party planning To Take Title To This dam Should Consider The Cost of rectifying The Aforementioned deficiencies and also would be Well Advised To retain a Consultant Engineer experienced in Design/restoration of earth Dams.

The Following Should be Considered by The Consultant in The Course of his Testing & Inspection:

- ① The Cutoff is an OAK PLANK Core WALL 102 Years old. IT Seems probable That This is in an advanced State of deterioration, but determination of its Condition is not ^{possible} by means of a Visual Inspection. Upper Pool Elevation is $3\frac{1}{2}' \pm$ below The Spillway Invert and There is Still Saturation of Portions of The downstream Face & downstream Areas beyond The Toe of Slope.

13. * Overall Condition: (Continued on Sheet 3A)

1. Safe _____
2. Minor repairs needed _____ ☒
3. Conditionally safe - major repairs needed ^{To} _____ ☒
4. Unsafe _____
5. Reservoir impoundment no longer exists (explain)
Recommend removal from inspection list _____

* Note: Exact determination Should be made Through an in-depth Inspection.

(12) (continued)

INSPECTION REPORT

② The Department's 2/2/72 [^] showed an 8" pipe emerging beyond The ~~Balanced~~ Cut. grouted Fieldstone downstream Headwall. Field inspection Reveals That This pipe is No longer IN Evidence. There is a steady discharge From a point Approximately located where This pipe should be. Above This point There is ^{small} leakage Through The Toe of The Headwall. [^] Deltas of silt are visible IN The Pool downstream OF The Headwall.

③ The 24" Discharge sluice (Flowing Full at The Time of inspection) is Scouring a hole ~~at~~ below its discharge End. Some Kind of Stilling Pool (energy dissipator) Should be Constructed Here.

④ AT The downstream Toe near The Southerly End of The dam There is an 8' \pm dia Pool several Feet deep adjacent To what appears To be a balanced Fieldstone headwall. This would indicate The existence

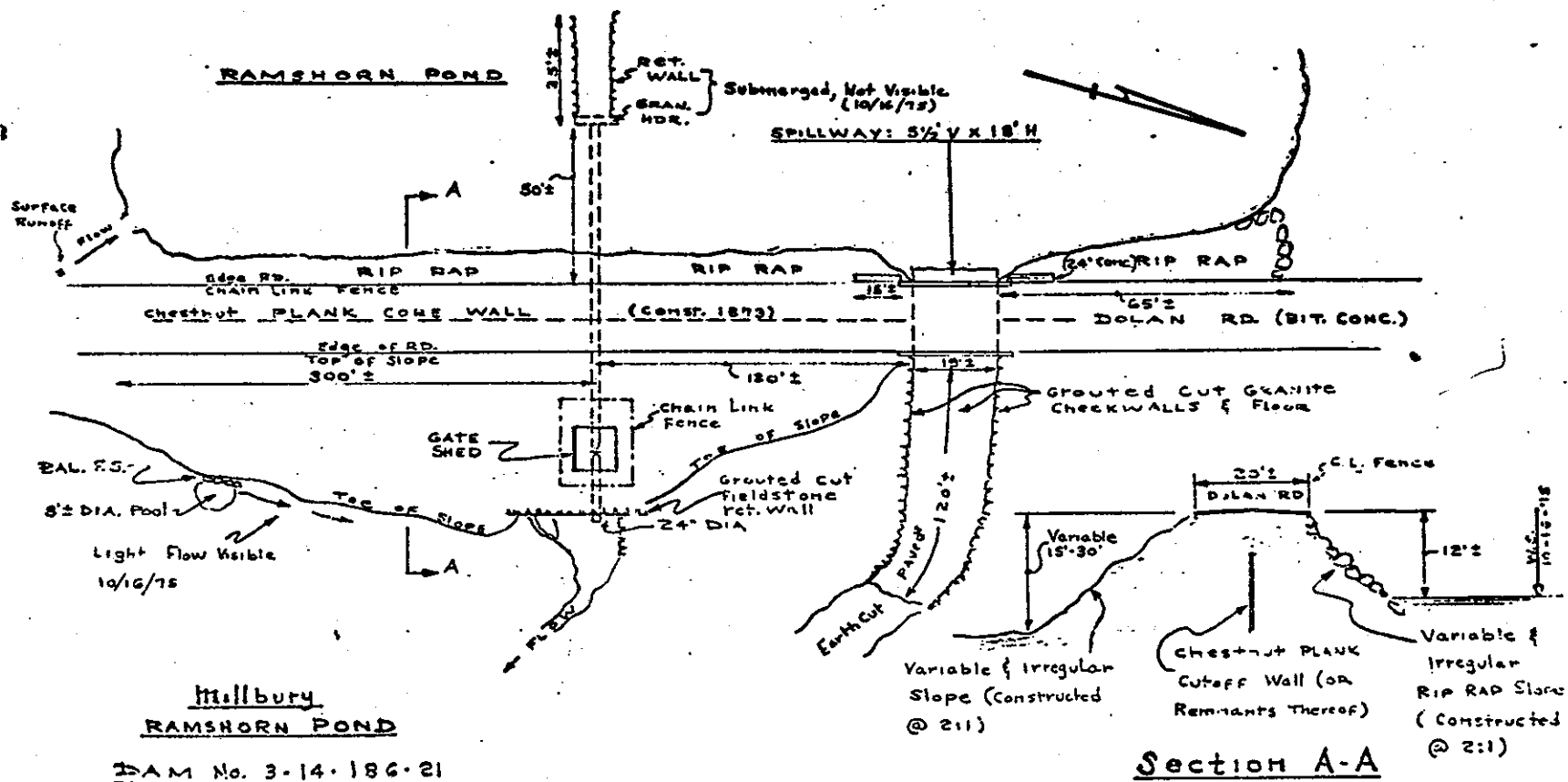
Millbury - RAMSHORN POND

DAM No. 3-14-186-21

12-④ (Continued)

of an old Stone box Sluice, But The
1939 Plan (on Record @ The County Engineers)
which Shows The dam Substantially in It's
Present Form, Shows No Such Structure.
There is light Flow out of This pool
Northward along The descending Toe of
The d.s. Slope.

B-16



APPENDIX C
PHOTOGRAPHS



NO. 1 - SPILLWAY INLET AND HEADWALL



NO. 2 - FLASHBOARDS AND WALKWAY AT SPILLWAY INLET



**NO. 3 - SPILLWAY CHANNEL UNDER DOLAN ROAD
UPSTREAM VIEW**



NO. 4 - UPSTREAM DAM FACE SHOWING EROSION AT TOP OF SLOPE

APPENDIX D
HYDROLOGIC AND HYDRAULIC COMPUTATIONS

(I) Broad Crested Spillway - $Q_s = CLH^{1.5}$ [Ref. pp. 360-362]

$$C = 3.27 + 0.4 \frac{H}{h} ; L = L' - 0.1NH$$

H = Physical Water Head on CREST (h_v not included)

h = Weir Height, L' = Measured Crest Length

Assumptions

For Floods or Peak Flows, $\frac{H}{h} \approx 0.5 \therefore C = 3.47$

$$L = 90\% L'$$

$$\therefore Q_s = 3.12 L' H^{3/2}$$



(II) Flow over Crest of Dam - $q_c = 3.475 \left[\frac{y}{y+h'} \right]^{1/2} (H')^{3/2}$ [Ref pp 52-3]

q_c = Disch./ft. of width

$H' \neq h'$ as defined above; $y = h' + H'$

Assumptions

For Floods (flow over dam crest)

$$H' = \frac{1}{6} h' \text{ [note } h' \approx h + H \text{ in Item (I) above]}$$

$$\therefore y = \frac{7}{6} h' \neq \left[\frac{y}{y+h'} \right]^{1/2} = \left[\frac{7/6 h'}{13/6 h'} \right]^{1/2} = 0.734$$

$$\therefore q_c = 2.55 (H')^{3/2}$$

Apply to Crest in steps where levels are roughly const.

Rev 7/5/78 LEB

IV Summary of Discharge vs Pond Elev.

1st Range 625.5 to 631.1 ; $Q_s = 9(18.17)(7.09)H^{3/2} = 50.53 H^{3/2}$

Pond Elev.	with 18" Flashbds		No Flashboards	
	H ft	Q cfs	H ft	Q cfs
625.5			0	0
627.0	0	0	1.5	93
628.0	1	50.5	2.5	200
629.0	2	143	3.5	331
630.0	3	263	4.5	482
631.0	4	404	5.5	652
631.1	4.1	419	5.6	670

2nd Range 632.56 to 632.65 ; Q_{wu} = Values from Hydr. Tables w/ $p = 8'$
 $L = 0.9(18.17) = 16.35'$

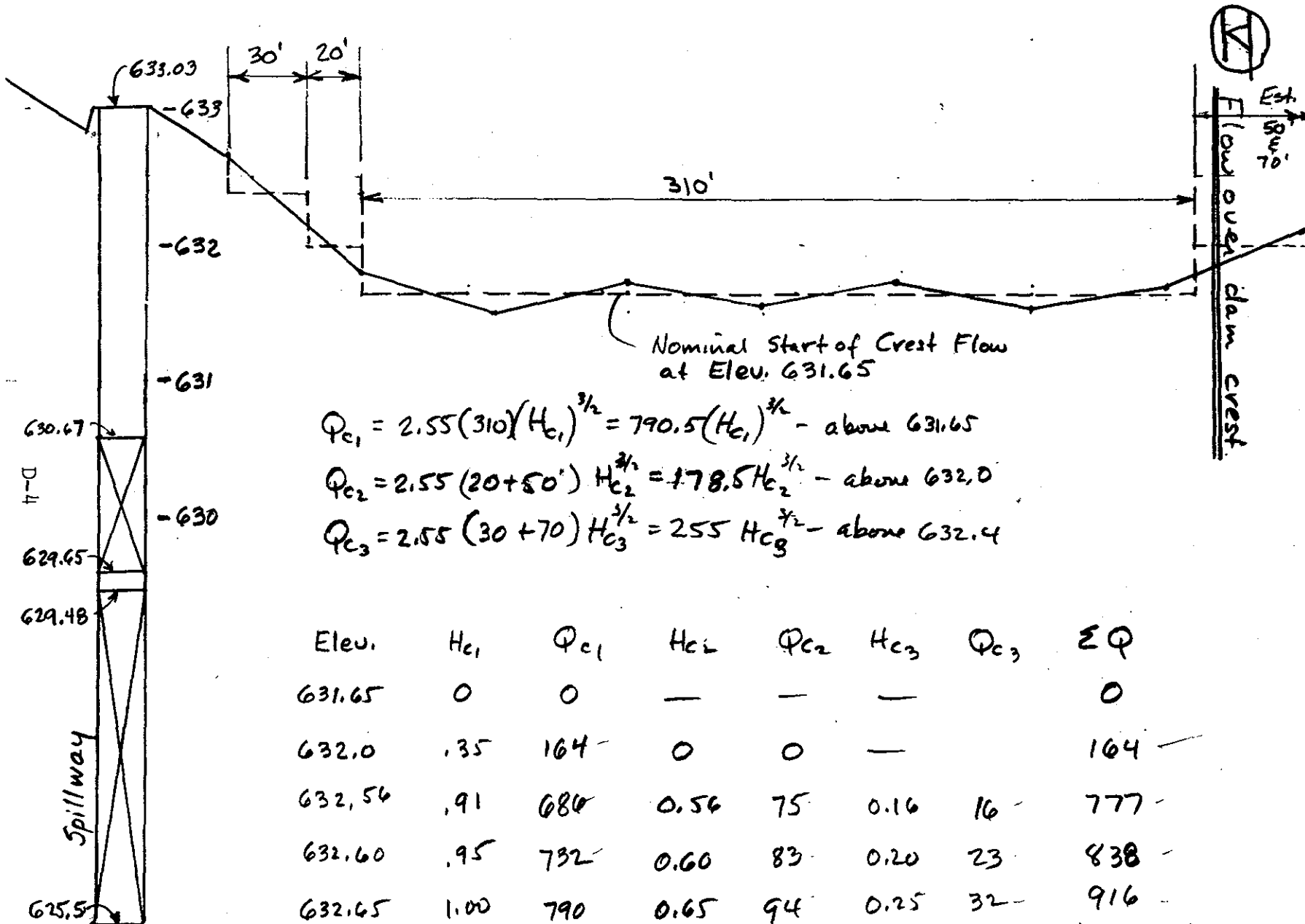
Pond Elev.	h_u'	Q_{wu}	h_L'	Q_{0L}	Total Q
629.65	0	0	4.15	543	543
630.15	0.5	45	4.65	574	619
631.15	1.50	93	5.65	633	726

3rd Range Above 632.65

Pond Elev.	h_u''	C_D	Q_u	h_L''	Q_L	Total Q
631.50	1.85	0.63	115	6.00	653	768
632.00	2.35	0.62	127	6.50	679	806
633.00	3.35	0.62	152	7.50	730	882

METCALF & EDDY, ENGINEERS

Project Nat. Rev. of Non-Fed. Dams Acct. No. 5864 Page D-4 of 10
 Subject Worcester, Mass. Area Compd. By LEB Date 6/19/78
 Detail Rams Horn Pond CK'd By EMC Date 6/26/78



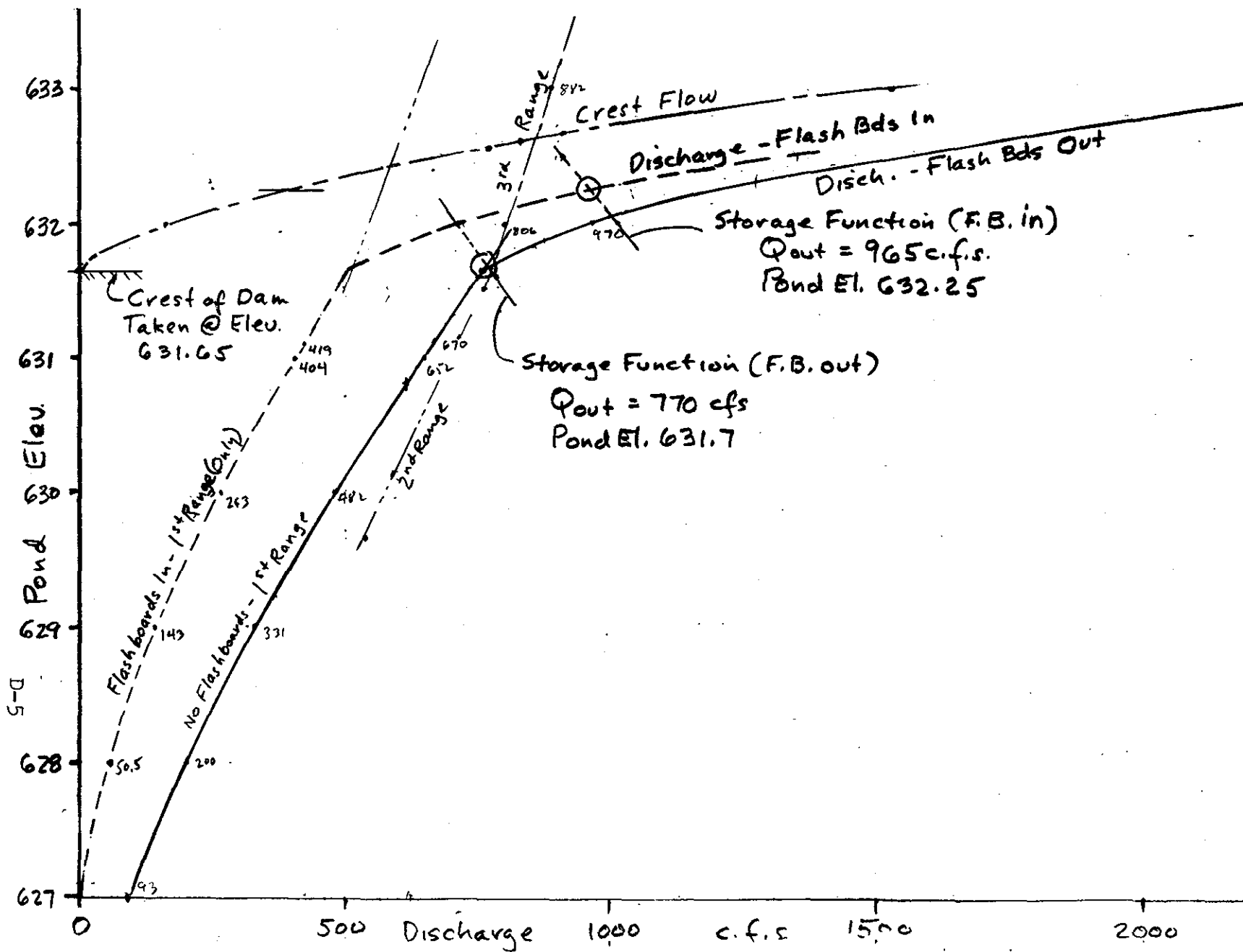
$$Q_{c1} = 2.55(310)(H_{c1})^{3/2} = 790.5(H_{c1})^{3/2} - \text{above } 631.65$$

$$Q_{c2} = 2.55(20+50')(H_{c2})^{3/2} = 178.5(H_{c2})^{3/2} - \text{above } 632.0$$

$$Q_{c3} = 2.55(30+70)(H_{c3})^{3/2} = 255(H_{c3})^{3/2} - \text{above } 632.4$$

Elev.	H_{c1}	Q_{c1}	H_{c2}	Q_{c2}	H_{c3}	Q_{c3}	ΣQ
631.65	0	0	—	—	—	—	0
632.0	.35	164	0	0	—	—	164
632.56	.91	686	0.56	75	0.16	16	777
632.60	.95	732	0.60	83	0.20	23	838
632.65	1.00	790	0.65	94	0.25	32	916
633.00	1.35	1240	1.00	179	0.60	118	1537

METCALF & EDDY, ENGINEERS



Project At. Review of Non Fed. Dams Acct. No. 5864 Page D-5 of 10
 Subject Worcester, Mass., Area Compd. By LEB Date 6/15/78
 Detail Ramsborn Pond CK'd. By EMG Date 6/15/78
 Reun 7/19/78 LEB

(VI) Peak Flow Rates

Measured Pond Areas - 0.215 mi^2

Estimated Swamp " - $0.205 "$

Total P&S Area 0.420 mi^2

Drainage Area 2.40 mi^2

$$\text{Ratio } \frac{P\&S \text{ Area}}{D.A.} = \frac{0.42}{2.4} = 0.175 = 17.5\% \text{ P\&S}$$

Slope of D.A. less P&S; Area = $2.40 - .42 = 1.98 \text{ mi}^2$

Est. $0.30 \text{ mi}^2 @ 11\% \text{ slope}$ } Ave. Slope 5.9 - Say 6%
 " $1.68 " @ 5\% "$

Using Max. Prob. Flood - Peak Flow Rates as supplied
 by C. of E. and as amplified by M&E -

For 2.4 mi^2 D.A. - est P.F.R. @ 1700 c.f.s./mi^2

For Size of Dam: Inflow Test Flood = $\frac{1}{2}(1700)(2.4 \text{ mi}^2) = 2040 \text{ c.f.s.}$

(VII) Storage Function

$$Q_{\text{Final}} = 2040 \left(1 - \frac{S_F}{9.5}\right) = 2040 - 300S = F$$

$$S = D12 \left(\frac{0.19}{2.4}\right) = 0.95D$$

S = Storage in terms of inches on D.A.; D = Storage Depth in Feet

A. Flash Boards In: Elev. 632', $Q_{\text{out}} = 730$, $S = 4.75"$, $F = 1019 \text{ c.f.s.} > Q_{\text{out}}$

Elev. 632.5, " = 1350, $S = 5.22"$, $F = 917 " < Q_{\text{out}}$

From Disch-Elev. Curve: $Q_F = 965 \text{ c.f.s. w/ Pond @ El. 632.25$

B. Flash Boards Out: Elev. 631.65, $Q_{\text{out}} = 750$, $S = 5.84"$, $F = 784 \text{ c.f.s.} > Q_{\text{out}}$

Elev. 632.0, $Q_{\text{out}} = 970$, $S = 6.18"$, $F = 712 " < Q_{\text{out}}$

From Disch-Elev. Curve: $Q_F = 770 \text{ c.f.s. w/ Pond @ El. 631.7$

C. Crest Flow - Flash Boards In - Only

$$Q = 2.55(632.25 - 631.65)^{1.5} = 1.19 \text{ c.f.s.}$$

$$y_c = 0.35' ; V_c = 3.4 \text{ fps.}$$

VIII 100 yr Freq. Storm Runoff, Pond Elev. & Flow Rate

(A) Using 4.7 in in 6 hrs as the 100 yr. frequency rainfall and a minimum "infiltration" rate of 0.18 in/hr. (50% type B & 50% type C soils) for a loss in 6 hours of 1.1 inches, the P.F.R. for 100 yr. is est. as:

$$\left(\frac{4.7 - 1.1}{19 - 1.1} \right) (4080) = \boxed{820 \text{ cfs } 100 \text{ yr P.F.R. \#1}}$$

(see below)

With $Q_1 = 820$, Pond Elev = 632.05, Stor. = 11.4 in. mi² on Pond or Stor. = 4.75 in on water shed.

Since above Runoff for 100 yr. storm was based on 4.7 - 1.1 = 3.6 in on basin, recalculate 100 yr P.F.R. as follows:

(B) 1: Max T_c based on 5000' @ 3.1% Slope to Swamp, plus 2200' @ 0.5% slope thru swamp. (Use Fig 3-1, S.C.S.-T.R. No 55)

$$V_1 = 0.45 \text{ fps. } T_{c1} = \frac{5000}{0.45} = 3.09 \text{ hr.}$$

$$V_2 = 0.5 \text{ fps. } T_{c2} = \frac{2200}{0.5} = 1.22 \text{ hr.}$$

$$\text{Say } T_c = 4.3 \text{ hr.}$$

$$\begin{aligned} \text{-2: } 100 \text{ yr. - 3 hr rainfall} &= 3.8 \text{ in.} = 1.27 \text{ in/hr.} \\ 100 \text{ yr. - 6 hr. } &= 4.7 \text{ in.} = 0.78 \text{ in/hr.} \end{aligned}$$

$$\text{Interpolate 4.3 hr rainfall from: (Rainfall)}^{3.25} = \frac{\text{Hours}}{0.0392} \left[\begin{array}{l} \text{Reg. -} \\ \text{Horse made} \\ \text{Relation} \end{array} \right]$$

$$4.3 \text{ hr. rainfall} = \underline{4.24 \text{ in}}$$

-3: Vol. of Runoff in 4.3 hr. w/ 4.24 in of rain

$$\text{Stor.} = 0.42 \text{ mi}^2 (4.24 \text{ in}) + \left[4.24 \text{ in} - 4.3(0.18) \right] (2.40 - 0.42) = 8.64 \text{ in mi}^2$$

$$\text{Pond Elev.} = 630.8 ; \boxed{Q_1 = 620 \text{ cfs } - 100 \text{ yr P.F.R. \#2}}$$

VIII 100 yr Freq. Storm Runoff, Pond Level & Peak Flow Rate

(C) Assume Infiltration @ 0.18 in/hr. (50% B + 50% C Soils - S.C.S.)

Hours	(A) Total Rainfall	(B) Runoff (in)	(C)* E.R.O. Vol in-mi ²	Initial Pond Elev.	Ave Disch cfs	Corrected Elev.	Corrected E.R.O.	Max Disch
0.5	2.2"	2.1"	5.1	629.25 (370)	185	629.15	4.96	
1.0	2.7"	2.5"	6.1	629.60 (420)	395	629.45	5.66	
2.0	3.3"	3.0"	7.3	630.00 (482)	451	629.70	6.16	} 430 cfs
3.0	3.8"	3.3"	8.1	630.05 (496)	489	629.70	6.20	
6.0	4.7"	3.6"	9.1	630.10 (500)	498	629.15	4.89	
12.0	5.7"	3.6"	9.5					
24.0	6.8"	2.5"	7.8					

* Col. (C) = 2.4 mi² x (B) + 0.42 mi² (A - B) to elim. runoff in pond.

From Above Q = 430 cfs, 100 yr P.F.R. #3

(X) Dam Failure Wave

Storage @ Spillway Crest: 700,000,000 gal. = 2148 Ac. ft.

Storage above Spillway to El. 632.45: 12.6 in mi² = 672 " "

Total Stored @ Failure 2820 " "

Length of Dam @ Mid Height = 295' ; 40% = 118'

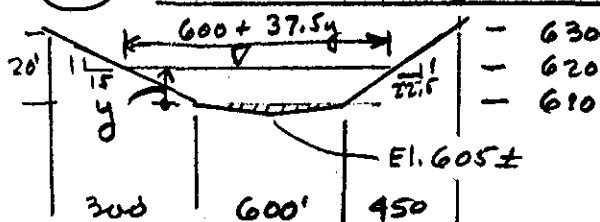
$$Y_0 = 632.45 - 616.8 = 15.65$$

$$Q_p = \frac{B}{27} W_b \sqrt{g} (Y_0)^{3/2} = \frac{B}{27} (0.4)(295) \sqrt{32.2} (15.65)^{3/2} = 12283 \text{ cfs}$$

METCALF & EDDY, ENGINEERS

(XI) Flood Discharge Channel

(Approx 1600' dn. str. fr. dam)



$$\text{Slope} = \frac{10'}{1.45(2000'/11)} = 0.003448$$

$$S^{1/2} = 0.05872$$

Flow thru swamp & wooded area

$$\text{Use } n = 0.10$$

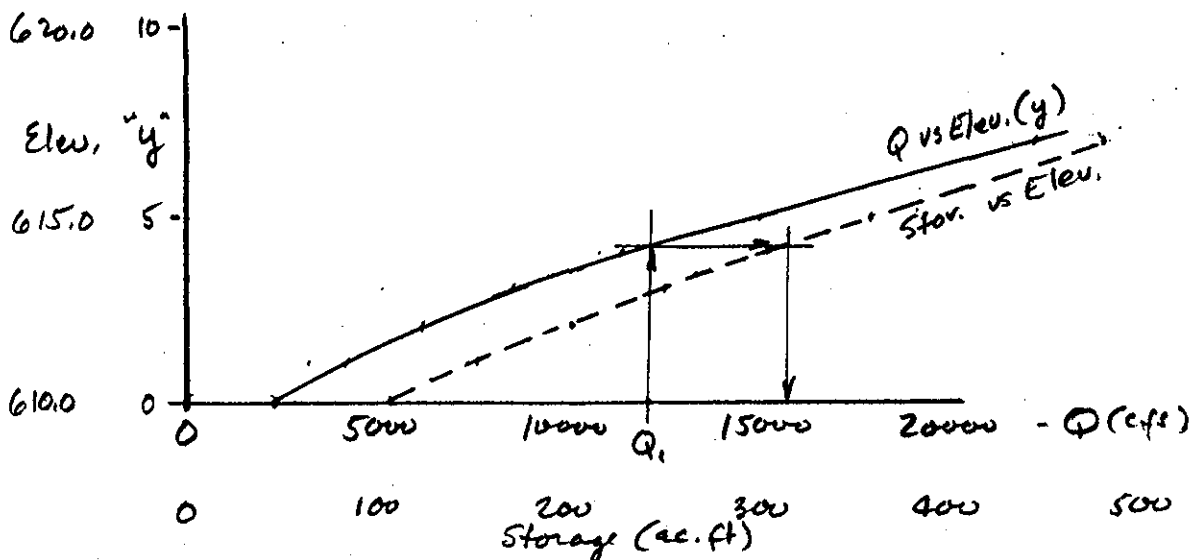
$$V = \frac{1.49}{0.1} (0.05872) R^{4/3} = 0.875 R^{4/3}$$

$$A = 600y + 37.5\left(\frac{1}{2}\right)y^2 + 1500$$

$$B = 600 + 37.5y \approx \text{Wet. Perim.} = P$$

Elev.	y	A	P	R ^{4/3}	Vel.	Q	
610.0	0	1500	600	1.842	1.612	2418	
610.5	.5	1805	618.7	2.042	1.786	3225	
611.0	1.0	2119	637.5	2.227	1.949	4130	
611.5	1.5	2442	656.2	2.401	2.101	5131	
612.0	2.0	2775	675.	2.566	2.246	6231	
613.0	3.0	3469	712.5	2.823	2.514	8719	
614.0	4.0	4200	750.0	3.153	2.759	11589	
615.0	5.0	4969	782.5	3.489	3.053	15169	
617.0	7.0	6619	862.5	3.89	3.40	22533	486
619.0	9.0	8419	937.5	4.32	3.78	31829	

(XI) Cont. $Vol. = (2 \text{ Reach}) (Area \text{ of } K\text{-Sect}) (\frac{1}{43560}) = \text{Ac. ft.}$
 $Vol. = 0.07346 (\text{Area})$



For $Q_1 = 12283$, $V_1 = 320 \text{ Ac. ft.}$

Trial $Q_2 = 12283 (1 - \frac{320}{2148}) = 10453$; $V_2 = 280 \text{ Ac. ft.}$

Ave $\bar{V} = 300 \text{ Ac. ft.}$

$\therefore Q_2 = 12283 (1 - \frac{300}{2148}) = 10567 \text{ cfs @ Ave Depth of } 3.7'$

Add 5' for L.P. in section.

Thus ave depth @ center of flood = 8.7'

Note: Depth below crest of dam $\approx 14.5'$ (from 1939 dwg.) - Say 16' (w/F.F. Bk)

Area of Surface = 0.19 mi² = 121.6 ac.

Assume Horiz Area Increases Linearly w/ Depth

Area = Depth $(\frac{121.6}{16'})$; $\Delta Vol = (A_n + A_{n+1})$ - use 2' increments

Depth	0	2	4	6	8	10	12	14	16	At Top Flash Board
Area (Ac)	0	15.2	30.4	45.6	60.8	76.0	91.2	106.4	121.6	
incr. Vol.		15.2	45.6	76.0	106.4	136.8	167.2	197.6	228.0	
$\Sigma Vol.$		15.2	60.8	136.8	243.2	380.0	547.2	744.8	972.8	Ac. ft.

$\therefore \text{Storage @ Failure} = 973 + 672 = 1645 \text{ Ac. ft.}$

Trial $Q_2 = 12283 (1 - \frac{320}{1645}) = 9894 \text{ cfs}$, $V_2 = 270$, $\bar{V} = \frac{590}{2} = 29.5$

$Q_2 = 12283 (1 - \frac{29.5}{1645}) = 10080 \text{ cfs}$; $y = 3.5'$ Not Much Difference

APPENDIX E
INVENTORY FORMS